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Geographical variations and factors associated with HIV testing prevalence in Ghana

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Abstract

Objective: To examine the factors associated with HIV testing and to develop an HIV testing prevalence surface map using spatial interpolation techniques to identify geographical areas with low and high HIV testing rates in Ghana.

Design: Secondary analysis of Demographic and Health Survey (DHS)

Setting: Rural and urban Ghana

Participants: The study sample comprised 13,777 reproductive age adults between age 15 and 49.

Results: In all, a total of 13,777 respondents comprising 68% females and 32% males were included in the analysis. We found that 40% of the population of Ghana had ever undergone HIV testing with higher odds/prevalence of lifetime testing among females, those with secondary education or higher, urban dwellers, residents of wealthy households, those with least one lifetime sexual partner and urban residents. Also, the highest HIV testing prevalence was observed in central and southern parts of the country while the lowest prevalence was found in the northern parts of the country. The surface map further revealed intraregional level differences in HIV testing estimates.

Conclusion: Given the results, HIV testing must be expanded with equitable testing resource allocation that target areas within the regions in Ghana with low HIV testing prevalence. Male should be encouraged to be tested for HIV.

Keywords: HIV testing; Spatial Analysis; Complex Sample Design; HIV prevention

Strengths and limitations of this study

- This study used a large, nationally representative survey dataset that employed a robust methodology for analysis
- A large number of people in sub-Saharan Africa are unaware of their HIV status, thereby missing the opportunity for care and treatment
- There are limited studies on spatial analysis to reveal intraregional level differences in HIV testing in Ghana
- The cross-sectional design of this study precluded any causal inference
- HIV testing must be expanded with equitable testing resource allocation that target areas within the regions in Ghana with low HIV testing

Introduction

Despite the progress made in advancing knowledge and antiretroviral treatment, human immunodeficiency virus (HIV) continues to cause high number of deaths and morbidity globally.^{1 2} Globally, about 37.9 million people were living with HIV in 2018¹. Sub-Saharan Africa (SSA) alone accounts for over 70% of people living with HIV, although it is home to only about 12% of the global population.³ Testing programs may help to estimate the prevalence and predictors of the disease towards developing context-specific policy actions to combat the disease. However, a large number of people in SSA are unaware of their HIV status, thereby missing the opportunity for care and treatment.⁴

Knowing HIV status is the first and critical step towards eradicating AIDS.⁵ Therefore, the Joint United Nations Programme on HIV/AIDS (UNAIDS) set the “90-90-90 target” to be achieved by the end of 2020⁶. The target has called for 90% of people living with HIV are to be aware of their HIV status, 90% of those diagnosed with HIV to have access to antiretroviral therapy (ART), and 90% of those receiving ART to achieve suppression of the viral loads.⁶ Sadly, the well-established HIV prevention tools are few amidst the mitigating factors affecting the desire for and uptake of HIV testing such as stigma, and therefore early diagnosis and early ART needs to be prioritized.⁷⁻⁹ The limitation of the HIV testing-care-treatment continuum may adversely affect the achievement of the global “90-90-90” target.

In Ghana, HIV is epidemiologically described as mature, mixed, and generalised.¹⁰ Recent studies report HIV prevalence of about 1.6% among the general population.^{11 12} The epidemic is largely driven by heterosexual contact and mother-to-child transmission,¹³ and also varies among groups and geographical locations.^{11 14} There are regional and geographical variations, with the highest prevalence reported in Eastern, Western, Greater Accra¹¹ and Volta

region,¹⁵ and the lowest in the three northern regions.¹¹ Nevertheless, there is limited literature data on intra-regional variations in HIV testing rate in Ghana. This knowledge is important in identifying low testing zones in high testing regions and high testing zones in low testing regions for targeted testing interventions. In Ghana, HIV testing is offered in hospitals and clinics with testing compulsory for women attending antenatal clinics. It is necessary for citizens to know their HIV status in order to receive treatment and help curb the incidence of new infections. Therefore, the current study aimed to examine factors associated with HIV testing and spatial interpolation of the prevalence of HIV testing in Ghana using the nationally representative Demographic and Health Survey data. Understanding the geographic distribution of HIV testing will help public health officials and policy makers equitably distribute resources to areas that are less likely to be tested and to help reduce the spread of the virus.

Methods

Patient and Public Involvement

Our study analysed a publicly available secondary data (GDHS 2014) from the demographic and health surveys database. Thus, patients and the public were not involved.

Study Design

This paper employed an analysis of secondary data using the 2014 Ghana Demographic and Health Survey (GDHS).¹⁶ As a cross-country survey, the GDHS is conducted to assess the general health of the population with special focus on maternal and child health indicators as well as other themes of global health importance such as the prevalence of HIV prevalence, testing and treatment. The 2014 Ghana DHS data collection was operationalized by the Ghana Statistical Service (GSS) and the Ghana Health Service (GHS) with funding from the U.S. Agency for International Development and other international donors. Technical support was also provided

by the ICF international. The census frame used for the 2014 GDHS consisted of all enumeration areas demarcated during the 2010 Ghana’s Population and Housing Census. The 2014 GDHS adopted a multistage sampling in enrolling households and individuals. The first stage involved the random selection of clusters (enumeration areas). The second stage involved using systematic sampling to select households to be interviewed from clusters that had already been selected during the first stage. Sampling was also stratified to account for rural and urban variations. In all, 216 and 211 clusters were selected from urban and rural areas, respectively, making a total of 427 clusters. On average, about 30 households were chosen from each selected cluster constituting a total of 12,831 selected households in the 2014 GDHS. The probability of cluster selection was proportional to the cluster size and independent at each sampling stratum. The probability of cluster selection was proportional to the size of the cluster size and independent at each sampling stratum.

Measurements

The outcome variable under investigation was HIV testing. This was assessed for each adult respondent in the survey by asking whether they had ever tested for HIV with a binary outcome (Yes/No). The following sociodemographic and behavioural factors were included are: sex, age, education level, marital status, religion, total number of lifetime sexual partners, history of sexually transmitted infections (STIs), household wealth index, place and region of residence. Household wealth index was already calculated and reported in the DHS data. It was estimated using household socioeconomic indicators such as the main roof and floor material of households, type of toilet facilities, source of drinking water, source of domestic cooking fuel, possession of television, radio, vehicle, motorcycles, agricultural land, farm animals amongst other movable and immovable assets. The GDHS employed a factor analysis to allot weights to

every household asset and a cumulative score was calculated from the allotted weights.

Households were graded according to the aggregate scores. Aggregate wealth scores were classified using a percentage distribution and categorised into quintiles using discrete cut points.

Poorest households were defined as wealth scores less than or equal to the 20th percentile ;

poorer households were those with scores greater than 20th percentile but less than or equal to

40th percentile ; middle households were those with aggregate scores greater than the 40th

percentile and less than or equal to the 60th percentile score ; households with aggregate scores

greater than the 60th percentile but less than or equal to the 80th percentile while households with

aggregate scores greater than the 80th percentile were assigned as richest households.

Data collection, access, preparation, and analysis

Data collection was done by trained enumeration officials from GSS. As part of the data collection, respondents were asked to if they had ever undergone testing for HIV. Data on other sociodemographic variables were collected as described above. The 2014 GDHS data used for analysis in this study is easily accessible at www.dhsprogram.com and can be freely downloaded after online request by individuals. Data was downloaded from the DHS program website after permission was obtained by the primary author, initially prepared in SPSS and analysed using STATA 16. The female and male data were separately downloaded comprising 9396 and 4388 cases, respectively. These were subsequently merged making a total of 13,784 cases. Five cases with incomplete data on HIV testing were dropped along with 2 other cases with missing data on history of STI. A total of 13,777 cases were included in the final analysis. The key variables were selected and included in the final analysis using univariate, bivariate and multivariate approaches. We stratified bivariate analysis by gender and assessed for the presence of interaction effect of gender on the association between each study covariate and HIV testing among Ghanaians. The

presence of significant interaction was assessed with adjusted Wald Test. Multivariate estimates of the factors associated with HIV testing was performed for the entire sample and separately for male and female sub-samples. We accounted for sample weight in the univariate and bivariate analysis. In the multivariate analysis, we used a complex survey design in STATA to account for sampling design. This was achieved using the “svyset” command to account for clusters or primary sampling units (n=427), sample strata (n=20) and sample weights. We used a generalized linear model (glm) with family set to “Poisson” to report prevalence ratio (PR) estimates instead of using a standard logistic regression used to report odds ratio. We reported both crude and adjusted PR estimates.

Spatial Analysis

We also performed spatial analysis to visualize HIV testing at the sub-regional level using clusters as the focus of the analysis. This was done using the prevR package in the R freeware for statistical analysis.¹⁷ This package was specifically developed to perform spatial estimation of regional trends of a prevalence using data from complex surveys involving two-staged sampling.¹⁷ With the aid of the functions available in the prevR package, we used the kernel estimator approach with adaptive bandwidths of equal number of persons surveyed to produce a surface of HIV testing rate.¹⁷ The main surface is an estimated HIV testing surface with parameter N=161, a value chosen using the Noptim() function in the prevR package.¹⁷ We used the “foreign” package in R to read the data in R whiles using “ggplot2” and “maptools” packages to demonstrate the HIV testing rate map. Spatial analysis was done using R version 3.5.3.¹⁸

Ethical considerations

Ethical approval for the 2014 Ghana DHS data collection was obtained from the Ethical Review Committee of the Ghana Health Service and the Institutional Review Board of ICF International. Enumerators obtained consent for enrolment from all respondents on behalf of GSS and the DHS program. We did not obtain any further consents. The application of spatial maps raises concerns for potential identification of respondents in their households on maps, especially for sensitive topic such as HIV testing in West Africa. However, this was addressed as the spatial data included only the Global Positioning System (GPS) coordinates of the centre points of the clusters instead of the actual location of individual households. Moreover, GPS coordinates of the centre points of the clusters were displaced at a random angle by up to 2 km and 5 km for urban and rural clusters, respectively. Additionally, GPS locations for about 1% of the rural clusters were displaced by 10 km. This helps to ensure that the actual households will not be identifiable on maps, but the trade-off is that it makes the spatial analysis less accurate.

Results

In all, a total of 13,777 respondents comprising 68% females and 32% males were included in the analysis. More than half, (59%) had attained secondary school education and 55% were currently married. For sexual history, 26%, 22% and 22% reported having had 1, 2 and 3-4 lifetime sexual partners, respectively. A majority (95%) reported no history of STI in the last 12 months preceding the survey. More than half (53%) of the respondents resided in the urban areas. Household wealth index was evenly distributed (Table 1). In all, 5546 respondents representing less than half (40%) of the total respondents had ever undergone HIV testing with 82% female and 18% male. Bivariate analysis showed that gender, age, education, marital status, religion,

total number of lifetime sexual partners, household wealth, place of residence and region of residence were significantly associated with having ever tested for HIV. (Table 1).

Table 1: Bivariate analysis of association between HIV testing variables (N = 13,777)

Variables	Ever tested for HIV		Sample N = 13,777 n (%)	p- value
	No N=8232 n (%)	Yes N=5546 n (%)		
Gender				<0.001
Female	4838 (58.8)	4551 (82.1)	9389 (68.1)	
Male	3394 (41.2)	994 (17.9)	4388 (31.9)	
Age				<0.001
15-19	2206 (26.8)	273 (4.9)	2479 (18.0)	
20-24	1306 (15.9)	895 (16.1)	2201(16.0)	
25-29	977 (11.9)	1216 (21.9)	2193 (15.9)	
30-34	839 (10.2)	1083 (19.5)	1922 (14.0)	
35-39	795 (9.7)	971 (17.5)	1766 (12.8)	
40-44	877 (10.7)	609 (11.0)	1486 (10.8)	
45-49	839 (10.2)	372 (6.7)	1211 (8.8)	
50+	393 (4.8)	126 (2.3)	519 (3.8)	
Education				<0.001
No formal education	1509 (18.3)	752 (13.6)	2261 (16.4)	
Primary	1487 (18.1)	773 (13.9)	2260 (16.4)	
Secondary	4854(59.0)	3288 59.3)	8142 (59.1)	
Post-Secondary	3824.6)	732 (13.2)	1114 (8.1)	
Marital status				<0.001
Never married	3816 (46.4)	1140 (20.6)	4956 (36.0)	
Currently married	3753 (45.6)	3855 (89.5)	7608 (55.2)	
Previously married	663 (8.1)	550 (9.9)	1213 (8.8)	
Religion				<0.001

Catholic	859 (10.4)	565 (10.2)	1424 (10.3)	
Protestant Christians	1029 (12.5)	880 (15.9)	1909 (13.9)	
Pentecostal/Charismatic	2975 (36.1)	2209 (39.8)	5184 (37.6)	
Other Christians	1276 (15.5)	915 (16.5)	2191 (15.9)	
Islam	1402 (17.0)	792 (14.3)	2194 (15.9)	
Traditional/Spiritualist	298 (3.6)	53 (1.0%)	351 (2.5)	
No religion/others	392 (4.8)	132 (2.4)	524 (3.8)	
Missing	1 (0.0)	0(0.0)	1 (0.0)	
Total lifetime sexual partners				<0.001
0	1829 (22.2)	183 (3.3)	2012 (14.6)	
1	1964 (23.9)	1606 (29.0)	3570 (25.9)	
2	1461 (17.7)	1596 (28.8)	3057 (22.2)	
3-4	1567 (19.0)	1454 (26.2)	3021 (21.9)	
5-9	803 (9.8)	452 (8.2)	1255 (9.1)	
10+	585 (7.1)	245 (4.4)	830 (6.0)	
Undisclosed	23 (0.3)	9 (0.2)	33 (0.2%)	
Had any STI last 12 months				0.220
No	7880 (95.7)	5276 (95.1)	13156 (95.5)	
Yes	345 (4.2)	264 (4.8)	619 (4.4)	
Don't Know	6 (0.1)	6 (0.1)	12 (0.1)	
Household wealth index				<0.001
Poorest	1700 (20.7%)	563 (10.2%)	2263 (16.4%)	
Poorer	1634 (19.8%)	780(14.1%)	2414 (17.5%)	
Middle	1735 (21.1%)	1035 (18.7%)	2770 (20.1%)	
Richer	1684 (20.5%)	1393 (25.1%)	3077 (22.3%)	

Richest	1479 (18.0%)	1774 (32.0%)	3253 (23.6%)	
Rural/Urban Residence				<0.001
Urban	3940 (47.9%)	3393 (61.2%)	7333 (53.2%)	
Rural	4292 (52.1%)	2152 (38.8%)	6444 (46.8%)	
Region				<0.001
Western	950 (11.5)	589 (10.6)	1540 (11.2)	
Central	774 (9.4)	583 (10.5)	1356 (9.9)	
Greater Accra	1451(17.6)	1368 (24.7)	2819 (20.5)	
Volta	669 (8.1%)	387 (7.0)	1057 (7.7)	
Eastern	754 (9.2)	552 (10.0)	1306 (9.5)	
Ashanti	1530 (18.6)	1056 (19.0)	2586 (18.8)	
Brong Ahafo	696 (8.5%)	436 (7.9%)	1132 (8.2)	
Northern	857 (10.4)	285 (5.1)	1142 (8.3)	
Upper East	347 (4.2)	178 (3.2)	526 (3.8)	
Upper West	203 (2.5)	111 (2.0)	314 (2.3)	
All percentage values in the table represent column %				

Multivariate analysis of predictors of HIV testing revealed that the following variables were independent significant predictors of HIV testing in Ghana: sex, age, education level, marital status, religion, total lifetime sexual partners, household wealth index and region of residence.

The likelihood of HIV testing was greater in females relative to males [APR: 1.98, 95% CI :1.79 - 2.19]. Relative to people in the age group 15-19 years, those aged 20-24 had higher likelihood of HIV Testing [APR: 2.05, 95% CI :1.71 - 2.46]. Similar pattern was observed for other older age groups 20-24yrs, 25-29yrs, 30-34yrs, 35-39yrs, 40-44yrs, and 50+yrs except for the 45-49years age group (Table 2). Relative to respondents with no education, those with primary,

secondary and higher education were 12%[APR:1.12 ,95% CI :1.03 - 1.23],32%[APR:1.32, 95% CI :1.21 -1.43] and 88% [APR:1.88, 95% CI :1.69 - 2.08] more likely to undergo HIV testing, respectively (Table 2). Relative to those who had never been married, the likelihood of HIV testing was higher among those who were currently married [APR: 1.62, 95% CI: 1.51 - 1.74] as well as those who were previously married [APR: 1.47, 95%CI: 1.33 - 1.62]. HIV testing was found to be higher among respondents with at least one total lifetime partner relative to those with no sexual history (Table 2). Moreover, those who did not disclose the number of sexual partners were more likely to have undergone HIV testing. Likewise, compared to the people from poorest household, higher likelihood of HIV testing was found among those in poorer, middle, rich and richest households (Table 2). People residing in the Upper East Region had greater likelihood of undergoing HIV Testing as compared to those living in the greater Accra Region [APR:1.21, 95% CI: 1.02 -1.43]. Place of residence and history of STI were not found to be significant independent predictors of HIV testing. HIV testing was 44% less likely among Traditional believers compared to Catholics in Ghana (APR: 0.56, 95% CI: 0.41- 0.77).

Table 2. Crude and multivariate estimates of the likelihood of HIV testing in Ghana (N= 13,777)

Covariates	Crude Estimates		Adjusted Estimates	
	PR [95% CI of PR]	p-value	APR [95% CI of PR]	p-value
Gender				
Male	Reference		Reference	
Female	2.14 [1.96 - 2.33]	<0.001	1.98 [1.79 - 2.19]	<0.001
Age				
15-19	Reference		Reference	
20-24	3.70 [3.16 - 4.32]	<0.001	2.05 [1.71 - 2.46]	<0.001
25-29	5.04 [4.27 -5.94]	<0.001	2.18 [1.79 - 2.65]	<0.001

30-34	5.12 [4.30 - 6.10]	<0.001	2.12 [1.73 - 2.59]	<0.001
35-39	4.99[4.25 - 5.88]	<0.001	2.03 [1.68 - 2.45]	<0.001
40-44	3.72 [3.10 - 4.47]	<0.001	1.64 [1.33 - 2.01]	<0.001
45-49	2.79 [2.25 - 3.45]	<0.001	1.23 [0.98 - 1.56]	0.072
50+	2.20 [1.74 - 2.80]	<0.001	1.58 [1.22 - 2.04]	<0.001
Education				
No formal education	Reference		Reference	
Primary	1.03 [0.92 - 1.15]	0.626	1.12 [1.03 - 1.23]	0.012
Secondary	1.21 [1.09 - 1.35]	<0.001	1.32 [1.21 -1.43]	<0.001
Post-Secondary	1.98 [1.76 - 2.22]	<0.001	1.88 [1.69 - 2.08]	<0.001
Marital status				
Never married	Reference		Reference	
Currently married	2.20 [2.03 - 2.39]	<0.001	1.62 [1.51 - 1.74]	<0.001
Previously married	1.97 [1.78 - 2.18]	<0.001	1.47 [1.33 - 1.62]	<0.001
Religion				
Catholic	Reference		Reference	
Protestant Christians	1.16 [1.04 - 1.30]	0.008	1.04 [0.95 - 1.15]	0.335
Pentecostal/Charismatic	1.07 [0.98 - 1.17]	0.118	0.96 [0.89 - 1.04]	0.387
Other Christians	1.05 [0.93 - 1.19]	0.420	1.01 [0.92 - 1.11]	0.776
Islam	0.91 [0.82 - 1.01]	0.084	1.05 [0.95 - 1.16]	0.307
Traditional/Spiritualist	0.38 [0.27 - 0.53]	<0.001	0.56 [0.41- 0.77]	<0.001
No religion/others	0.63 [0.53 - 0.76]	<0.001	0.80 [0.67 - 0.96]	0.016
Total lifetime sexual partners				
0	Reference		Reference	
1	4.95 [4.11 - 5.95]	<0.001	2.31 [1.86 - 2.88]	<0.001
2	5.75 [4.79 - 6.89]	<0.001	2.39 [1.92-2.97]	<0.001
3-4	5.30 [4.35 - 6.44]	<0.001	2.27 [1.80 - 2.86]	<0.001
5-9	3.96 [3.26 - 4.82]	<0.001	2.21 [1.74 - 2.82]	<0.001
10+	3.25 [2.55 - 4.15]	<0.001	2.20 [1.67 - 2.90]	<0.001

Undisclosed	3.17 [1.56 - 6.42]	< 0.001	1.65 [0.90 - 3.02]	<0.001
Had any STI last 12 months				
No	Reference		Reference	
Yes	1.08 [0.95 - 1.22]	0.223	0.99 [0.89 - 1.10]	0.893
Don't Know	1.23 [0.59 - 2.58]	0.572	1.12 [0.57 - 2.17]	0.742
Household wealth index				
Poorest	Reference		Reference	
Poorer	1.30 [1.14 - 1.47]	<0.001	1.17 [1.05-1.30]	0.003
Middle	1.50 [1.32 - 1.70]	<0.001	1.21 [1.08 - 1.36]	0.001
Richer	1.82 [1.59 - 2.07]	<0.001	1.42 [1.24 - 1.63]	<0.001
Richest	2.19 [1.92-2.50]	<0.001	1.53 [1.32 - 1.78]	<0.001
Rural/Urban Residence				
Urban	Reference		Reference	
Rural	0.72 [0.66 - 0.79]	<0.001	0.96 [0.87 - 1.05]	0.345
Region				
Western	0.79 [0.68 - 0.92]	0.002	0.96 [0.85 - 1.10]	0.624
Central	0.88 [0.77-1.01]	0.069	1.05 [0.93 - 1.17]	0.398
Greater Accra	Reference			
Volta	0.75 [0.65 - 0.88]	<0.001	1.05 [0.92 - 1.20]	0.432
Eastern	0.87 [0.76 - 0.99]	0.049	1.09 [0.96 - 1.23]	0.186
Ashanti	0.84 [0.73 - 0.97]	0.020	0.97 [0.86 - 1.08]	0.594
Brong Ahafo	0.79 [0.68- 0.92]	0.003	1.05 [0.92 - 1.20]	0.437
Northern	0.51 [0.39 - 0.67]	<0.001	0.86 [0.70 - 1.07]	0.181
Upper East	0.70 [0.59 - 0.82]	<0.001	1.21 [1.02 - 1.43]	0.026
Upper West	0.73 [0.61 - 0.86]	<0.001	1.13 [0.94 - 1.35]	0.174
PR: Prevalence Ratio; APR: Adjusted Prevalence Ratio; CI: Confidence Intervals				

Effect modification of gender on the relationship between each sociodemographic variable and HIV testing in Ghana

Gender was found to be a significant effect modifier on the relationship between HIV testing and all the sociodemographic variables under investigation : age ($p < 0.001$), marital status ($p < 0.001$), household wealth index ($p < 0.001$), educational level ($p < 0.001$), type of religion ($p < 0.001$), total number of lifetime sexual partners ($p < 0.001$), STI status in the past 12 months ($p < 0.001$), place of residence ($p < 0.001$), and region of residence ($p < 0.001$) Table 3.

Table 3. Crude estimates of the likelihood of HIV testing in Ghana stratified by gender (N= 13,777)

	Male n= (4388)	Female n=(9389)	
	PR [95% CI of PR]	PR [95% of PR]	Adjusted Wald test
Age			< 0.001
15-19	Reference	Reference	
20-24	3.08 [2.19 - 4.35]	3.56 [2.98 - 4.24]	
25-29	4.92 [3.49 - 6.94]	4.75 [3.94 -5.72]	
30-34	5.02 [3.53 - 7.14]	4.90 [4.04 - 5.93]	
35-39	5.80 [4.13 - 8.14]	4.57 [3.83 - 5.44]	
40-44	5.43 [3.83 - 7.71]	3.29 [2.68 - 4.03]	
45-49	4.63 [3.29 - 6.52]	2.36 [1.85 - 2.99]	
50+	4.25[2.99 - 6.03]		
Education			<0.001
No formal education	Reference	Reference	
Primary	1.16 [0.81 - 1.67]	1.07 [0.95 - 1.21]	
Secondary	2.11 [1.56 - 2.85]	1.28[1.14 - 1.44]	
Post-Secondary	5.33 [3.87 - 7.35]	1.93 [1.71 - 2.19]	
Marital status			<0.001

Never married	Reference	Reference	
Currently married	1.66 [1.43 - 1.92]	2.25 [2.06 - 2.45]	
Previously married	1.79[1.33 - 2.40]	1.82[1.64- 2.02]	
Religion			<0.001
Catholic	Reference	Reference	
Protestant Christians	1.15 [0.92 - 1.45]	1.14 [1.02 - 1.29]	
Pentecostal/Charismatic	0.77 [0.62 - 0.96]	0.09 [0.99 - 1.20]	
Other Christians	0.90 [0.68 - 1.19]	1.11 [0.99 - 1.25]	
Islam	0.65 [0.51 - 0.82]	1.00 [0.89 - 1.12]	
Traditional/Spiritualist	0.36 [0.21 - 0.60]	0.43 [0.30 -0.59]	
No religion/others	0.41 [0.26 - 0.64]	0.87 [0.70 - 1.08]	
Total lifetime sexual partners			p< 0.001
0	Reference	Reference	
1	2.44 [1.79 - 3.32]	5.58 [4.39 - 7.10]	
2	2.29 [1.70 - 3.10]	6.61 [5.22 - 8.38]	
3-4	3.12 [2.29 - 4.26]	6.29 [4.94 - 8.00]	
5-9	2.67 [1.94 -3.67]	6.34 [4.94 - 8.13]	
10+	2.82 [2.03 -3.92]	6.97 [5.14 - 9.46]	
Undisclosed	2.44 [0.91 - 6.50]	4.36 [1.57 -12.13]	
Had any STI last 12 months			<0.001
No	Reference	Reference	
Yes	0.80 [0.56- 1.14]	1.13 [1.00 -1.27]	
Don't Know	8.56e-09[1.65e-09 -4.44e-08]	1.13[0.59 - 2.16]	
Household wealth index			< 0.001
Poorest	Reference	Reference	
Poorer	0.98 [0.72 -1.34]	1.34 [1.16 - 1.55]	
Middle	1.42 [1.06 - 1.90]	1.47 [1.27 - 1.71]	

Richer	2.10 [1.66 - 2.67]	1.73 [1.49 - 2.01]	
Richest	3.28 [2.54 - 4.24]	1.97 [1.70 - 2.29]	
Rural/Urban Residence			<0.001
Urban	Reference	Reference	
Rural	0.59 [0.48 - 0.72]	0.76 [0.70 - 0.82]	
Region			< 0.001
Western	0.70 [0.50 - 0.98]	0.81 [0.70 - 0.93]	
Central	0.78 [0.55 - 1.10]	0.90 [0.81 - 1.00]	
Greater Accra	Reference		
Volta	0.71 [0.50 - 0.99]	0.76 [0.66 - 0.88]	
Eastern	0.83 [0.60 - 1.15]	0.88 [0.78 - 0.99]	
Ashanti	0.61 [0.43 - 0.87]	0.88 [0.77 - 1.00]	
Brong Ahafo	0.50 [0.36 - 0.70]	0.86 [0.75 - 0.99]	
Northern	0.44 [0.29 - 0.66]	0.53 [0.39 - 0.71]	
Upper East	0.67 [0.49 - 0.93]	0.70 [0.59 - 0.82]	
Upper West	0.66 [0.44 - 0.98]	0.74 [0.62 - 0.88]	

Gender variations in the strength of association between HIV testing and sociodemographic factors

The factors independently associated with HIV testing in Ghana were generally the same for males and females with some noteworthy exceptions within categories of each covariates. Moreover, although the direction of the association was generally the same for most variables in both males and females, the strength of association varied by gender in some instances (Table 4). For example, increasing age was associated with higher likelihood of HIV testing in both males and females but the magnitude of association was generally larger for males than females. Moreover, age group 45-49yrs had significantly higher likelihood of having undergone HIV of testing compared to 15-19yrs among males but the finding was not significant among females.

Primary education in males did not have any significant effect on HIV testing among males but was significantly associated with 10% increased likelihood of HIV testing in females. Unlike males, current and previous marriage among females were significantly associated with increased likelihood of HIV testing. Males respondents who were Protestant Christians were had lower likelihood of ever having HIV testing compared to their Catholic counterparts but this association was not present among females. Conversely, females Muslims were less likely to undergo HIV testing compared to female Catholics but this association was not observed among males.

Increasing number of total lifetime sex partner was significantly associated with higher likelihood of undergoing HIV testing among females but this association was absent in males. Another noteworthy gender variation was observed for the effect of household wealth on HIV testing: Any increase in household wealth category was associated with higher likelihood of HIV testing among females with the poorer, middle, richer and richest household reporting greater likelihood of HIV testing compared to the poorest. However, only the richer and richest households were significantly associated with higher likelihood of HIV testing among the males. Males residing in the Upper East region were more likely to have undergone HIV testing as compared to their counterparts residing in the Greater Accra Region, the regional capital (Table 4).

Table 4: Multivariate estimates of HIV testing stratified by Gender

	Male	Female
	APR [95% CI]	APR [95% CI]
Age		
15-19	Reference	Reference
20-24	2.59 [1.76 - 3.84]	1.90 [1.57 -2.30]
25-29	3.59 [2.35 - 5.49]	1.99 [1.61- 2.45]

30-34	3.81 [2.48 - 5.85]	1.94 [1.57 - 2.40]
35-39	4.41 [2.88 - 6.77]	1.79 [1.47 - 2.18]
40-44	4.65 [2.980 - 7.26]	1.34 [1.08 - 1.67]
45-49	3.80 [2.48 - 5.82]	0.99 [0.77 - 1.27]
50+	3.69 [2.36 - 5.77]	-
Education		
No formal education	Reference	Reference
Primary	1.38 [0.93 - 2.04]	1.10 [1.01 - 1.21]
Secondary	1.95 [1.37 - 2.78]	1.29 [1.19 - 1.41]
Post-Secondary	3.07 [2.08 - 4.53]	1.68 [1.51 - 1.86]
Marital status		
Never married	Reference	Reference
Currently married	1.02 [0.85 - 1.24]	1.73 [1.60 - 1.86]
Previously married	1.15 [0.85 - 1.55]	1.52 [1.35 - 1.69]
Religion		
Catholic	Reference	Reference
Protestant Christians	1.05 [0.86 - 1.29]	1.05 [0.96 - 1.17]
Pentecostal/Charismatic	0.79 [0.65 - 0.97]	1.01 [0.93 - 1.10]
Other Christians	0.95 [0.76 - 1.17]	1.03 [0.94 - 1.12]
Islam	0.87 [0.69 - 1.08]	1.12 [1.01 - 1.24]
Traditional/Spiritualist	0.53 [0.31 - 0.91]	0.58 [0.42 - 0.81]
No religion/others	0.57 [0.37 - 0.87]	0.94 [0.76 - 1.18]
Total lifetime sexual partners		
0	Reference	Reference
1	1.13 [0.83 - 1.53]	3.06 [2.35 - 3.99]
2	1.01 [0.73 - 1.39]	3.23 [2.48 - 4.21]
3-4	1.19 [0.87 - 1.63]	3.01 [2.29 - 3.96]
5-9	1.04 [0.73 - 1.47]	3.07 [2.31 - 4.08]
10+	1.02 [0.72 - 1.43]	3.77 [2.74 - 5.19]
Undisclosed	0.94 [0.33 - 2.64]	2.04 [0.97 - 4.28]

Had any STI last 12 months		
No	Reference	Reference
Yes	0.83 [0.59 - 1.16]	1.04 [0.93 - 1.15]
Don't Know	5.49e-06[8.14e-07 - .000037]	1.13[0.59 - 2.17]
Household wealth index		
Poorest	Reference	Reference
Poorer	0.85 [0.61 - 1.19]	1.21 [1.08 - 1.37]
Middle	1.17[0.84 - 1.63]	1.20[1.06 - 1.36]
Richer	1.77 [1.32 - 2.36]	1.34 [1.15 - 1.56]
Richest	2.28 [1.60 - 3.25]	1.38 [1.17 - 1.62]
Rural/Urban Residence		
Urban	Reference	Reference
Rural	1.14 [0.93 - 1.40]	0.93 [0.85 - 1.01]
Region		
Western	1.03 [0.79 - 1.33]	0.95 [0.84 - 1.08]
Central	1.08 [0.82 - 1.43]	1.03 [0.94 - 1.14]
Greater Accra	Reference	Reference
Volta	1.34 [1.00 - 1.78]	0.99 [0.86 - 1.13]
Eastern	1.33 [1.00 - 1.78]	1.03 [0.92 - 1.16]
Ashanti	0.78 [0.57 - 1.06]	1.01 [0.91 - 1.12]
Brong Ahafo	0.92 [0.68 - 1.23]	1.07 [0.94 - 1.22]
Northern	1.14 [0.79 - 1.64]	0.80 [0.63 - 1.02]
Upper East	1.86 [1.33 - 2.62]	1.10 [0.92 - 1.31]
Upper West	1.43 [0.95 - 2.14]	1.07 [0.88 - 1.31]
APR: Adjusted Prevalence Ratio; CI: Confidence Intervals		

Map of Ghana showing Regional HIV Testing Prevalence by gender

The national HIV testing prevalence for Ghana is 40.3%. We stratified the national HIV testing prevalence by region and realized that the national estimate masked the prevalence at the regional

level (Figure 1). For instance, four regions in the south (Central, Ashanti, Eastern, and Greater Accra) have estimates higher than the national estimate and six of the remaining regions have estimates lower than the national estimate (Upper East, Upper West, Northern, Brong Ahafo, Western, and Volta). The regional prevalence map shows that the three northern regions in the northern part of the country (Upper East, Upper West, and Northern) have the lowest estimates of HIV testing prevalence in Ghana (Figure 1). The regional level HIV testing prevalence was further stratified by gender (S1 Table), represented on the map with a pie chart (Figure 1). The pie chart shows that HIV testing prevalence was higher among women than men in all the ten regions.

HIV testing prevalence in Ghana estimated by kernel estimator approach

Overall, the HIV testing surface map revealed that the national and regional level estimates mask sub-regional level variations in HIV testing (Figure 2). The general observation is that the areas with the highest HIV testing prevalence are in the southern regions while the lowest prevalence are found in the northern part of the country (Figure 2). Furthermore, the surface map revealed intra-regional level differences in HIV testing estimates. For instance, there are areas within each region with higher testing prevalence than others.

Discussion

This study conducted a multivariate analysis and spatial interpolation of the predictors of HIV testing in Ghana using nationally representative data, GDHS. To the authors’ knowledge, this is the first study to analyse factors that influence lifetime HIV test prevalence in Ghana together with spatial interpolation using the GDHS. We found that 2 out of 5 Ghanaians (40.3%) of reproductive age had undergone HIV testing. Our results have shown that sex, age, education level, marital status, religion, total lifetime sexual partners, household wealth index and region of residence were independent predictors of HIV testing in Ghana. The findings showed that being

female, being presently or previously married, having at least secondary education, living in an urban area, being a Christian and coming from a wealthy home were linked to a higher likelihood of being tested for HIV in Ghana.

The HIV testing rate found in our study (40%) was higher when compared to the same population in Sierra Leone (34%) but lower than Zambia (82%), Lesotho (85%) and Zimbabwe (89%).¹⁹ All the countries with high rates of HIV testing are located in southern Africa and the high rates of testing in these countries were attributed to high rates of HIV prevalence, mandatory HIV testing at prenatal clinics and mobile clinics for HIV testing to mitigate the high prevalence of the virus.¹⁹

There are some suggestive reasons for the relatively high HIV testing in Eastern, Greater Accra, and Central. The district—Lower Manya Krobo—that continually records the highest HIV prevalence in Ghana is in the Eastern region with current estimate of 5.56% HIV prevalence.²⁰ Therefore, HIV reduction programs by government and non-governmental organizations (NGOs) are concentrated in the Eastern region.²¹ HIV testing could be a proxy for access to healthcare facilities. Since the Greater Accra is the region with the highest number of healthcare facilities in Ghana, more people in the region may find it easy to screen for HIV.^{21 22} Our spatial interpolation revealed that there are areas in Ghana with higher HIV testing prevalence compared to the national and regional estimates. For example, in the Western Region, regional HIV testing prevalence ranged 35.7% – 38.4%, however, the spatial interpolation identified some clusters to be as low as 20% and some as high as 50%. Hence the importance of applying spatial interpolation in population-based studies to unmask the hidden details which can help design targeted interventions.

Females in general had greater likelihood of HIV testing compared to their male counterparts, although below the national and global 90-90-90 targets, this is in agreement with previous studies.^{11 23} This can partly be explained by the fact that HIV testing for women during prenatal care which aims at reducing mother-to-child transmission of HIV.^{24 25} We found that compared to all age groups, adolescents between ages 15 and 19 years tend to have the lowest likelihood of getting tested for HIV. This finding is critical to public health because earlier studies have reported that higher rates of HIV infection among adolescents are more likely due to being engaged in risky behaviour and unsafe sex practices which put them at risk of contracting HIV.^{26 27} Therefore, health policy makers should target adolescents with health education and mass HIV testing. In Ghana, health testing such as breast cancer testing among older adult women have been reported to be associated with participation in club meetings.²⁸ Given that many youth clubs exist in Ghana, they could be encouraged and incentivised to add HIV testing to their club activities.

Our results showed that educational status was a significant predictor of HIV testing. People with higher education may have adequate knowledge and understanding of the implications of testing for HIV, thereby resulting in their likelihood to patronize testing services. Our finding concurs with previous studies,^{29 30} that reported positive relationship between education and HIV testing. We also found that wealth status predicts the likelihood of HIV testing in Ghana. Compared to the people from poorest household, we found a higher likelihood for HIV testing among those in poorer, middle, rich and richest households. This finding is consistent with previous studies.^{29 31 32} The cost associated with the testing could be a barrier for people with low socioeconomic status to get tested. These findings suggest the need for sensitization campaigns targeting communities and people with low level of education and

socioeconomic status to increase their awareness of the importance of HIV testing. This could be done through targeted outreach such as mobile clinics and integrating HIV testing into routine healthcare services, improving home-based and self-testing and subsidising the cost of the testing. Community leaders such as chiefs should also be involved in promoting HIV testing.

We found that those who were married or were previously married were more likely to be tested than those who were never married. In most African countries including Ghana, religious institutions and local governments require mandatory pre-marital HIV testing as a means to combat the spread of HIV among newly married couples.^{33 34} Therefore, married people have the possibility of being tested for HIV compared to their unmarried counterparts. Although contentious and said to be a source of stigmatization and human right violation to those who test HIV positive,^{32 33 35} mandatory pre-marital HIV testing is said to be an effective way of people knowing their status. Therefore, there is a need for collaboration between public health officials and other leaders such as religious and community leaders to partner to help improve HIV testing in the communities.

Our findings also highlighted some noteworthy variations in the factors associated with HIV testing between males and females. Primary education was significantly and independently associated with increased likelihood of HIV testing in females although it did not have the same effect among males. This finding is important because it reinforces the health value of universal basic education in Ghana and the need to encourage females to attain universal basic education for improved health outcomes. Also, the magnitude of the effect of increasing age on HIV testing was generally larger for males than females. Moreover, males in age groups 45-49yrs had significantly higher likelihood of having undergone HIV testing compared to males aged 15-19 years but the finding was not significant among females. This can be partly explained by the fact

that most women aged 45-49 might have reached menopause and their engagement in active sexual activities might have reduced³⁶ and hence were probability not targets for HIV testing by public health professional. On the contrary, their male counterparts are generally sexually active and were more likely to have been targeted for HIV testing by public health professionals.³⁷

Unlike males, current and previous marriage among females were significantly associated with increased likelihood of HIV testing. This observation can be explained by the fact sexual activities and childbirth is socially acceptable among marriage couples in Ghana.³⁸ For most females, marriage sometimes results in childbirth and HIV testing is done for all women who visit antenatal as part of the prevention of mother to child transmission policy in Ghana.³⁹ This service is generally exclusive for female pregnant females does not generally attract the males. We also found that increasing number of total lifetime sex partner was significantly associated with higher likelihood of undergoing HIV testing among females, but this association was absent in males. Increasing number of total lifetime sexual partners can be used as a proxy for risky sexual behaviour which can attract public health attention when females seek reproductive health services

Another noteworthy gender variation was observed for the effect of household wealth on HIV testing with the poorer, middle, richer and richest household reporting greater likelihood of HIV testing compared to the poorest. This finding implies that any policy which can increase the economic standings of households, no matter how small the change may be, has a benefit on health care utilization as far as HIV testing is concerned among females in Ghana. This finding is similar to a study conducted among the same population in Mozambique using the DHS dataset.³²

Strength and Limitation

The current study used a large, nationally representative survey data set and employed a robust methodology for analyses. We stratified our analysis by gender which revealed interesting findings which can guide policy to target each gender to ensure efficiency and effectiveness of policy interventions. We employed spatial interpolation techniques that have advantages over standard statistical techniques to identify geographical variations of HIV testing prevalence in Ghana. This may be of population health significance in the effort to meet the UNAIDS 90-90-90 target not only in Ghana but in other sub-Saharan African countries. Cluster analysis with the Scan Statistics method adjusts for population density and decreases selection bias as the clusters are explored without previous knowledge of their size, location or time period.⁴⁰ Furthermore, our study uncovered the population that is most at risk not being tested for HIV and geographical locations with low HIV testing in Ghana. These findings could serve as a framework for public health officials to design targeted intervention to increase HIV testing.

Our findings, however, are subject to limitations that must be taken into consideration. As characteristics of all cross-sectional studies, our study could neither establish temporality nor causality of the observed association. It is important to note that all the variables in this study were self-reported and this could have introduced recall or social desirability bias. Also, we were not able to ascertain the actual reasons for participant's prior HIV testing and therefore this was not accounted for in our analysis. Moreover, a limitation with the visualization of HIV testing using spatial maps is that the testing rate is dispersed across all pixels regardless of the presence or absence of population settlements. Despite these limitations, this study has provided profound insights from a population-level survey analysis as well as a spatial analysis of HIV testing prevalence in Ghana for informed public health action.

Conclusion

In conclusion, the study findings could help public health officials to better understand factors associated with HIV testing among the Ghanaian general population by showing the areas and at risk-population for targeted HIV intervention programs. We found that 40.3% of the population in Ghana have ever been screened for HIV – with females, those with secondary education or higher, urban dwellers, those married or previously married and those from wealthy homes more likely to be tested for HIV. The highest HIV testing prevalence was found in central and southern parts of the country while the lowest prevalence was found in the northern parts of the country. The spatial interpolated prevalence map further revealed intraregional level differences in HIV testing estimates. We also found gender variations in the factors associated with HIV testing which could guide policy interventions. Expansion of HIV testing, outreach through mobile clinics, home-based and self-testing, wide-ranging coverage through outreach programs, community-based approaches, and integration of opportunities or HIV testing during regular medical care are critical. These myriad approaches will be integral in reaching all persons with sub-clinical HIV infections in sub-Saharan Africa for life-saving treatment.

Figure Legends:

Figure 1: HIV Testing Prevalence by region

Figure 2: HIV testing prevalence in Ghana estimated by kernel estimator approach

Conflict of Interest

The authors declare that they have no competing interests.

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We did not receive any funding to conduct the current study.

Data sharing statement

The 2014 GDHS is publicly available upon a simple registration-access request so data used for this study can be obtained from the DHS website at

https://dhsprogram.com/data/dataset_admin/index.cfm.

Authors' contributions

All authors contributed to the design of the study. JJN obtained permission and downloaded datasets from DHS program website, and contributed to the drafting of the manuscript. HOD and PA contributed to the analysis of data and drafting of the manuscript. PAD, RKA and ED participated in the drafting of the manuscript. All authors critically reviewed the manuscript and approved the final manuscript.

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References

1. World Health Organization. HIV/AIDS: Data and Statistics 2018 [cited 2019. Available from: <https://www.who.int/hiv/data/en/> accessed August 10, 2019.

2. UNAIDS. Global HIV & AIDS statistics — 2019 fact sheet 2019 [cited 2020 June 20]. Available from: <https://www.unaids.org/en/resources/fact-sheet> accessed June 16 2020.

3. World Health Organization. HIV/AIDS Fact Sheet Geneva: World Health Organization 2019 [updated November 15, 2019]. Available from: <https://www.who.int/en/news-room/fact-sheets/detail/hiv-aids> accessed November 25 2019.

4. Kharsany AB, Karim QA. HIV infection and AIDS in sub-Saharan Africa: current status, challenges and opportunities. *The open AIDS journal* 2016;10:34.

5. Narin P, Yamamoto E, Saw YM, et al. Factors associated with HIV testing among the general male population in Cambodia: A secondary data analysis of the Demographic Health Survey in 2005, 2010, and 2014. *PloS one* 2019;14(7):e0219820.

6. UNAIDS. AIDS JUNPo: 90–90–90: an ambitious treatment target to help end the AIDS epidemic. *Geneva: UNAIDS* 2014

7. Asamoah CK, Asamoah BO, Agardh A. A generation at risk: A cross-sectional study on HIV/AIDS knowledge, exposure to mass media, and stigmatizing behaviors among young women aged 15–24 years in Ghana. *Global health action* 2017;10(1):1331538.

8. Gómez-Ayerbe C, Martínez-Sanz J, Muriel A, et al. Impact of a structured HIV testing program in a hospital emergency department and a primary care center. *PloS one* 2019;14(8):e0220375.

9. Koku EF. Stigma, sexual risk and desire for HIV tests in Ghana. *Sexual health* 2011;8(1):110–19.

10. Laar A, DeBruin D. Key populations and human rights in the context of HIV services rendition in Ghana. *BMC International Health and Human Rights* 2017;17(1):1–10.

11. Ali H, Amoyaw F, Baden D, et al. Ghana’s HIV epidemic and PEPFAR’s contribution towards epidemic control. *Ghana medical journal* 2019;53(1):59–62.

12. Addo SA, Abdulai M, Yawson A, et al. Availability of HIV services along the continuum of HIV testing, care and treatment in Ghana. *BMC Health Services Research* 2018;18(1):739.

13. Van Hulst M, Sagoe KW, Vermande JE, et al. Cost-effectiveness of HIV screening of blood donations in Accra (Ghana). *Value in Health* 2008;11(5):809–19.

14. John Nutor J, Duodu PA, Agbadi P, et al. Predictors of high HIV+ prevalence in Mozambique: A complex samples logistic regression modeling and spatial mapping approaches. *Plos one* 2020;15(6):e0234034.

15. Osei-Yeboah J, Lokpo SY, Ussher FA, et al. The Epidemiology of Human Immunodeficiency Virus (HIV) and Syphilis in Ghana: A Five-Year Single Urban Site Parallel Population-Based Analysis vis-à-vis the Sentinel Survey. *Journal of tropical medicine* 2018;2018

16. GSS G. Ghana statistical service (GSS), Ghana health service (GHS), and ICF macro. *Accra: Ghana Demogr Health Surv* 2009;2008:79–96.

17. Larmarange J, Vallo R, Yaro S, et al. Methods for mapping regional trends of HIV prevalence from Demographic and Health Surveys (DHS). *Cybergeo: European Journal of Geography* 2011

18. Team RC. R: A language and environment for statistical computing. 2013

19. Staveteig S, Croft TN, Kampa KT, et al. Reaching the 'first 90': Gaps in coverage of HIV testing among people living with HIV in 16 African countries. *PLoS One*

- 2017;12(10):e0186316. doi: 10.1371/journal.pone.0186316 [published Online First: 2017/10/13]
20. Ghana AIDS Commission. National HIV and AIDS Policy: Universal Access to HIV Prevention, Treatment and Care Services towards Ending AIDS as a Public Health Threat. Accra, Ghana. 2019 [cited 2020 July 1]. Available from: [https://www.ghanaidc.gov.gh/mcadmin/Uploads/nationalHIVandAIDSPolicy\(2\).pdf](https://www.ghanaidc.gov.gh/mcadmin/Uploads/nationalHIVandAIDSPolicy(2).pdf) accessed July 1 2020.
 21. Hushie M. Public-non-governmental organisation partnerships for health: an exploratory study with case studies from recent Ghanaian experience. *BMC Public Health* 2016;16(1):963.
 22. Tun W, Okal J, Schenk K, et al. Limited accessibility to HIV services for persons with disabilities living with HIV in Ghana, Uganda and Zambia. *Journal of the International AIDS Society* 2016;19:20829.
 23. Sanga Z, Kapanda G, Msuya S, et al. Factors influencing the uptake of Voluntary HIV Counseling and Testing among secondary school students in Arusha City, Tanzania: a cross sectional study. *BMC Public Health* 2015;15(1):452.
 24. Nyuzaghl J, Ohene S, Odoi-Agyarko K. Acceptability of routine offer of HIV Testing (opt-out approach) among pregnant women in the Wa municipality. *Ghana medical journal* 2011;45(1)
 25. Camlin CS, Ssemmondo E, Chamie G, et al. Men "missing" from population-based HIV testing: insights from qualitative research. *AIDS Care* 2016;28 Suppl 3(Suppl 3):67-73. doi: 10.1080/09540121.2016.1164806 [published Online First: 2016/07/16]
 26. Dellar RC, Dlamini S, Karim QA. Adolescent girls and young women: key populations for HIV epidemic control. *Journal of the International AIDS Society* 2015;18:19408.
 27. Kim YK, Small E, Okumu M. School-based HIV/AIDS education, risky sexual behaviors, and HIV testing among high school students in the United States. *Soc Work Health Care* 2019;58(3):258-73. doi: 10.1080/00981389.2018.1558163 [published Online First: 2018/12/18]
 28. Agyemang AF, Tei-Muno AN, Dzomeku VM, et al. The prevalence and predictive factors of breast cancer screening among older Ghanaian women. *Heliyon* 2020;6(4):e03838.
 29. Lépine A, Terris-Prestholt F, Vickerman P. Determinants of HIV testing among Nigerian couples: a multilevel modelling approach. *Health policy and planning* 2015;30(5):579-92.
 30. Mirandola M, Gios L, Joanna Davis R, et al. Socio-demographic factors predicting HIV test seeking behaviour among MSM in 6 EU cities. *The European Journal of Public Health* 2017;27(2):313-18.
 31. Agha S. Factors associated with HIV testing and condom use in Mozambique: implications for programs. *Reproductive Health* 2012;9(1):20.
 32. Agbadi P, Nutor JJ, Darkwah E, et al. Covariates and Spatial Interpolation of HIV Screening in Mozambique: Insight from the 2015 AIDS Indicator Survey. *International Journal of Environmental Research and Public Health* 2020;17(16):5630.
 33. Akoku DA, Tihnje MA, Tarh EO, et al. Predictors of willingness to accept pre-marital HIV testing and intention to sero-sort marital partners; risks and consequences: Findings from a population-based study in Cameroon. *PloS one* 2018;13(12):e0208890.
 34. Barmania S, Aljunid SM. Premarital HIV testing in Malaysia: a qualitative exploratory study on the views of major stakeholders involved in HIV prevention. *BMC international health and human rights* 2017;17(1):1-10.

35. Ifemeje S. Mandatory premarital HIV testing policy in Nigeria: a gross violation of the rights of people living with HIV/AIDS. *The International Journal of Human Rights* 2012;16(3):401-10.

36. Krasnow SS, Maglio A-S. Female sexual desire: what helps, what hinders, and what women want. *Sexual and Relationship Therapy* 2019:1-29.

37. Gewirtz-Meydan A, Ayalon L. Why do older adults have sex? Approach and avoidance sexual motives among older women and men. *The Journal of Sex Research* 2019;56(7):870-81.

38. Elleamoh GE, Dake FA. “Cementing” marriages through childbearing in subsequent unions: Insights into fertility differentials among first-time married and remarried women in Ghana. *PloS one* 2019;14(10):e0222994.

39. Ejigu Y, Tadesse B. HIV testing during pregnancy for prevention of mother-to-child transmission of HIV in Ethiopia. *PLoS One* 2018;13(8):e0201886. doi: 10.1371/journal.pone.0201886 [published Online First: 2018/08/10]

40. Chimoyi LA, Musenge E. Spatial analysis of factors associated with HIV infection among young people in Uganda, 2011. *BMC public health* 2014;14(1):555.

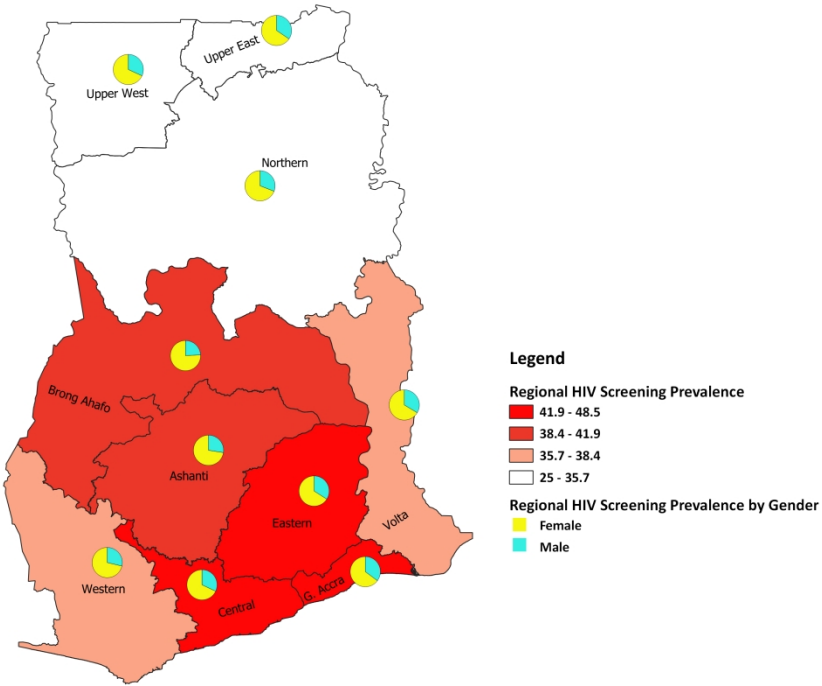


Figure 1: HIV Testing Prevalence by region

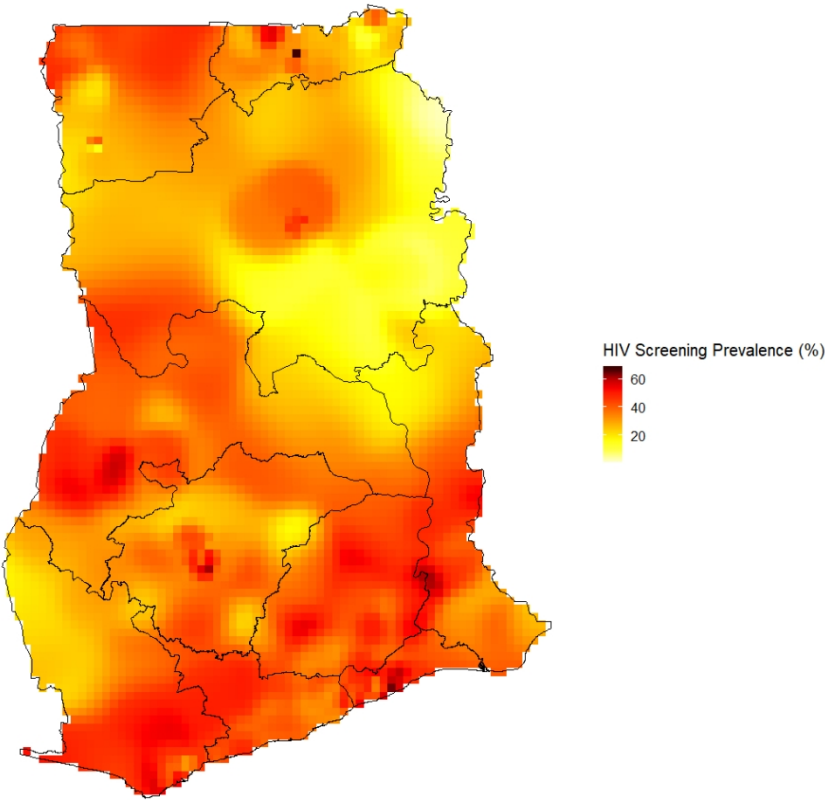


Figure 2: HIV testing prevalence in Ghana estimated by kernel estimator approach
317x277mm (96 x 96 DPI)

S1 Table 1 Regional HIV Screening Prevalence (%) by Gender

Region (n)	HIV Testing	Gender		p-value
		Female n(%)	Male n(%)	
Western (1540)	No	558 (53.8)	392 (78.1)	$p \leq 0.001$
	Yes	480 (46.2)	110 (18.6)	
Central (1357)	No	455 (48.6)	319 (75.8)	$p \leq 0.001$
	Yes	481 (51.4)	102 (24.2)	
Greater Accra (2819)	No	814 (42.9)	637 (69.0)	$p \leq 0.001$
	Yes	1082 (57.1)	286 (31.0)	
Volta (1057)	No	407 (56.5)	263 (78.0)	$p \leq 0.001$
	Yes	313 (43.5)	74 (22.0)	
Eastern (1307)	No	437 (49.8)	318 (74.1)	$p \leq 0.001$
	Yes	441 (50.2)	111 (25.9)	
Ashanti (2586)	No	891 (49.6)	639 (80.9)	$p \leq 0.001$
	Yes	905 (50.4)	151 (19.1)	
Brong Ahafo (1132)	No	389 (50.7)	307 (84.3)	$p \leq 0.001$
	Yes	284 (49.3)	57 (15.7)	
Northern (1142)	No	549 (69.8)	308 (86.5)	$p \leq 0.001$
	Yes	237 (30.2)	48 (13.5)	
Upper East (525)	No	215 (60.1)	132 (79.0)	$p \leq 0.001$
	Yes	143 (39.9)	35 (21.0)	
Upper West (314)	No	124 (57.7)	79 (79.8)	$p \leq 0.001$
	Yes	91 (42.3)	20 (20.2)	

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**Geographical variations and factors associated with HIV testing prevalence in Ghana:
spatial mapping and complex survey analyses of the 2014 demographic and health surveys**

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Abstract

Objective: To examine the factors associated with HIV testing and to develop an HIV testing prevalence surface map using spatial interpolation techniques to identify geographical areas with low and high HIV testing rates in Ghana.

Design: Secondary analysis of Demographic and Health Survey (DHS)

Setting: Rural and urban Ghana

Participants: The study sample comprised 9380 women and 3854 men of 15 through 49 years.

Results: We found that 13% of women and 6% of men of Ghana had tested for HIV in the past 12 months. For women, being within the age groups of 15-39 years, being currently married, attainment of post-secondary education, having only one sexual partner, and dwelling in certain regions with reference to greater Accra (Volta, Eastern, Upper West, and Upper East) were associated with a higher likelihood of HIV testing. For men, being older than 19 years, attainment of post-secondary education and dwelling in the Upper East region with reference to the greater Accra region were significantly associated with a higher likelihood of HIV testing. The surface map further revealed intraregional level differences in HIV testing estimates.

Conclusion: Given the results, HIV testing must be expanded with equitable testing resource allocation that target areas within the regions in Ghana with low HIV testing prevalence. Men should be encouraged to be tested for HIV.

Keywords: HIV testing; Spatial Analysis; Complex Sample Design; HIV prevention

Strengths and limitations of this study

- This study used a large, nationally representative survey dataset that employed a robust methodology for analysis
- A large number of people in sub-Saharan Africa are unaware of their HIV status, thereby missing the opportunity for care and treatment
- There are limited studies on spatial analysis to reveal intraregional level differences in HIV testing in Ghana
- The cross-sectional design of this study precluded any causal inference
- HIV testing must be expanded with equitable testing resource allocation that target areas within the regions in Ghana with low HIV testing

Introduction

Despite the progress made in advancing knowledge and antiretroviral treatment, the human immunodeficiency virus (HIV) continues to cause a high number of deaths and morbidity globally.^{1 2} Globally, about 37.9 million people were living with HIV in 2018¹. Sub-Saharan Africa (SSA) alone accounts for over 70% of people living with HIV, although it is home to only about 12% of the global population.³ Testing programs may help to estimate the prevalence and predictors of the disease towards developing context-specific policy actions to combat the disease. However, a large number of people in SSA are unaware of their HIV status, thereby missing the opportunity for care and treatment.⁴

Knowing HIV status is the first and critical step towards eradicating AIDS.⁵ Therefore, the Joint United Nations Programme on HIV/AIDS (UNAIDS) set the “90-90-90 target” to be achieved by the end of 2020⁶. The target has called for 90% of people living with HIV are to be aware of their HIV status, 90% of those diagnosed with HIV to have access to antiretroviral therapy (ART), and 90% of those receiving ART to achieve suppression of the viral loads.⁶ Sadly, the well-established HIV prevention tools are few amidst the mitigating factors affecting the desire for and uptake of HIV testing such as stigma, and therefore early diagnosis and early ART needs to be prioritized.⁷⁻⁹ The limitation of the HIV testing-care-treatment continuum may adversely affect the achievement of the global “90-90-90” target.

In Ghana, HIV is epidemiologically described as mature, mixed, and generalised.¹⁰ Recent studies report HIV prevalence of about 1.6% among the general population.^{11 12} The epidemic is largely driven by heterosexual contact and mother-to-child transmission,¹³ and also varies among groups and geographical locations.^{11 14} There are regional and geographical variations, with the highest prevalence reported in Eastern, Western, Greater Accra¹¹ and Volta

region,¹⁵ and the lowest in the three northern regions.¹¹ Nevertheless, there is limited literature data on intra-regional variations in HIV testing rate in Ghana. This knowledge is important in identifying low testing zones in high testing regions and high testing zones in low testing regions for targeted testing interventions. In Ghana, HIV testing is offered in hospitals and clinics with testing compulsory for women attending antenatal clinics. It is necessary for citizens to know their HIV status in order to receive treatment and help curb the incidence of new infections. Therefore, the current study aimed to examine factors associated with HIV testing and spatial interpolation of the prevalence of HIV testing in Ghana using the nationally representative Demographic and Health Survey data. Understanding the geographic distribution of HIV testing will help public health officials and policy makers equitably distribute resources to areas that are less likely to be tested and to help reduce the spread of the virus.

Methods

Patient and Public Involvement

Our study analysed publicly available secondary data (GDHS 2014) from the demographic and health surveys database. Thus, patients and the public were not involved.

Study Design

This paper employed an analysis of secondary data using the 2014 Ghana Demographic and Health Survey (GDHS).¹⁶ As a cross-country survey, the GDHS is conducted to assess the general health of the population with a special focus on maternal and child health indicators as well as other themes of global health importance such as the prevalence of HIV prevalence, testing and treatment. The 2014 Ghana DHS data collection was operationalized by the Ghana Statistical Service (GSS) and the Ghana Health Service (GHS) with funding from the U.S. Agency for International Development and other international donors. Technical support was also

provided by the ICF international. The census frame used for the 2014 GDHS consisted of all enumeration areas demarcated during the 2010 Ghana’s Population and Housing Census. The 2014 GDHS was undertaken from early September to mid-December 2014. The 2014 GDHS adopted a multistage sampling in enrolling households and individuals. The first stage involved the random selection of clusters (enumeration areas). The second stage involved using systematic sampling to select households to be interviewed from clusters that had already been selected during the first stage. Sampling was also stratified to account for rural and urban variations. In all, 216 and 211 clusters were selected from urban and rural areas, respectively, making a total of 427 clusters. On average, about 30 households were chosen from each selected cluster constituting a total of 12,831 selected households in the 2014 GDHS. The probability of cluster selection was proportional to the cluster size and independent at each sampling stratum. The probability of cluster selection was proportional to the size of the cluster size and independent at each sampling stratum.

Study setting

The study setting is the republic of Ghana. Ghana is a lower-middle-income country in West Africa with a population of about 25 million people at the time of the 2014 GDHS. It shares boundaries Togo on the east, Burkina Faso on the north and northwest, and Côte d’Ivoire on the west.¹⁶

Measurements

The outcome variable under investigation was HIV testing in the past 12 months. This was assessed for each adult respondent in the survey by asking how long ago they had tested for HIV. For our study, we recoded the variable and grouped the cases who tested for HIV in the past 12

months as “1” and all others as “0”. The following sociodemographic and behavioural factors were included are sex, age, education level, marital status, religion, the total number of sexual partners in the past 12 months, history of sexually transmitted infections (STIs), household wealth index, place and region of residence. The household wealth index was already calculated and reported in the DHS data. It was estimated using household socioeconomic indicators such as the main roof and floor material of households, type of toilet facilities, source of drinking water, source of domestic cooking fuel, possession of television, radio, vehicle, motorcycles, agricultural land, farm animals amongst other movable and immovable assets. The GDHS employed factor analysis to allot weights to every household asset and a cumulative score was calculated from the allotted weights. Households were graded according to the aggregate scores. Aggregate wealth scores were classified using a percentage distribution and categorised into quintiles using discrete cut points. Poorest households were defined as wealth scores less than or equal to the 20th percentile; poorer households were those with scores greater than 20th percentile but less than or equal to 40th percentile; middle households were those with aggregate scores greater than the 40th percentile and less than or equal to the 60th percentile score; households with aggregate scores greater than the 60th percentile but less than or equal to the 80th percentile while households with aggregate scores greater than the 80th percentile were assigned as richest households.

Data collection, access, preparation, and analysis

Data collection was done by trained enumeration officials from GSS. As part of the data collection, respondents were asked if they had ever undergone testing for HIV. Data on other sociodemographic variables were collected as described above. The 2014 GDHS data used for analysis in this study is easily accessible at www.dhsprogram.com and can be freely downloaded

after an online request by individuals. Data was downloaded from the DHS program website after permission was obtained by the primary author, initially prepared in SPSS and analysed using STATA 16. The women and men data were separately downloaded comprising 9396 and 4388 cases, respectively. For the women dataset, sixteen cases with incomplete data on HIV testing and the covariates were dropped. Five hundred and thirty-three (533) men of 50 years and above were excluded from the analyses for men using ‘subpop’ function associated with the ‘svy’ command to allow a balanced comparison with the women. One case (1) with missing information on the outcome variable in the men datasets was excluded. The final sample sizes used for the analyses were 9380 women and 3854 men of 15 through 49 years. The key variables were selected and included in the final analysis using univariate, bivariate and multivariable approaches. We stratified bivariate analysis by gender and assessed for the presence of interaction effect of gender on the association between each study covariate and HIV testing among Ghanaians. The presence of significant interaction was assessed with the adjusted Wald Test. Multivariate estimates of the factors associated with HIV testing was performed separately for men and women samples.

The “gvselect”—Best subsets variable selection—in STATA was used to identify the best features to build models that explain the variability in HIV testing among Ghanaian men and women samples. As the name suggests, the “gvselect” performs best subsets variable selection.¹⁷ The variable selection is based on “the Furnival-Wilson leaps-and-bounds algorithm” published in 1974,¹⁸ which is “applied using the log-likelihoods of candidate models, allowing variable selection to be performed on a wide family of normal and nonnormal regression models”¹⁷ This method is described in the works of Lawless and Singhal published in 1978.¹⁹ The log-likelihood, Akaike's information criterion (AIC), and the Bayesian information criterion (BIC) are reported

for the best regressions at each predictor quantity.¹⁷ Thus, the model with the lowest AIC value is preferred. These variables (with their labels) were included in the “gvselect” equation: aaaV013 (age), aaaV106 (Education), aaaV502 (marital status), Religyn (religion), SexPart (sex partners including partner in last 12 months), aaaV763A (history of STI), aaaV190 (household wealth index), aaaV025 (urban-rural residence), aaaV024 (region of residence) (Additional file 1, Additional file 2). Coefficient plots for both the women and men models were generated using the “coefplot”, which is used for plotting regression coefficients.

We accounted for sample weight in the univariate and bivariate analysis. In the multivariate analysis, we used a complex survey design in STATA to account for sampling design. This was achieved using the “svyset” command to account for clusters or primary sampling units (n=427), sample strata (n=20) and sample weights. We used a generalized linear model (glm) with family set to “Poisson” to report prevalence ratio (PR) estimates instead of using a standard logistic regression used to report the odds ratio. We reported both crude and adjusted prevalence ratios (APR).

Spatial Analysis

We also performed spatial analysis to visualize HIV testing at the sub-regional level using clusters as the focus of the analysis. This was done using the prevR package in the R freeware for statistical analysis.²⁰ This package was specifically developed to perform spatial estimation of regional trends of a prevalence using data from complex surveys involving two-staged sampling.²⁰ With the aid of the functions available in the prevR package, we used the kernel estimator approach with adaptive bandwidths of an equal number of persons surveyed to produce a surface of HIV testing prevalence.²⁰ The main surface is an estimated HIV testing surface with parameter (N=233 for women sample and N=201 for men sample), a value that is chosen using

the Noptim() function in the prevR package.²⁰ The maps with the smoothing circle radius contours (in kilometres) have been added as supplementary figures (Women: S1 Figure, Men: S2 Figure). We used the “foreign” package in R to read the data in R whiles using “ggplot2” and “maptools” packages to demonstrate the HIV testing prevalence map. Spatial analysis was done using R version 3.5.3.²¹

Ethical considerations

Ethical approval for the 2014 Ghana DHS data collection was obtained from the Ethical Review Committee of the Ghana Health Service and the Institutional Review Board of ICF International. Enumerators obtained consent for enrolment from all respondents on behalf of GSS and the DHS program. We did not obtain any further consents. The application of spatial maps raises concerns for potential identification of respondents in their households on maps, especially for a sensitive topic such as HIV testing in West Africa. However, this was addressed as the spatial data included only the Global Positioning System (GPS) coordinates of the centre points of the clusters instead of the actual location of individual households. Moreover, GPS coordinates of the centre points of the clusters were displaced at a random angle by up to 2 km and 5 km for urban and rural clusters, respectively. Additionally, GPS locations for about 1% of the rural clusters were displaced by 10 km. This helps to ensure that the actual households will not be identifiable on maps, but the trade-off is that it makes the spatial analysis less accurate.

Results

Sample description

Table 1 describes the women and men samples, highlighting the association between HIV testing in the past 12 months and sociodemographic factors. In all, 15-49 years old women (9380 cases)

and men (3854 cases) were included in the analysis. In terms of quinary age distribution, the women showed equal proportion for the first three quinary age groups (17% each), with a gradual decline in the proportions with increasing age in the subsequent quinary age groups. Conversely, 22% of the men were aged 15-19years, 15% each for the 20-25years and 26-30years groups, and gradual decline in proportion with increasing age in the subsequent quinary age groups just like the pattern observed among the women. About 57% and 65% of women and men had attained secondary education, respectively. Approximately 33% and 48% of the women and men had never been in a union at the time of the survey, respectively. Religious affiliation was mainly Pentecostal/Charismatic among the women (41%) and men (31%). Only one percent of the women had had more than one sexual partner within the last 12 months preceding the survey compared to 14% among their men counterparts. More women (54%) than men (53%) resided in urban areas.

About 13% of the women had screened and received results for HIV testing in the last 12 months preceding the survey compared to 6% in the men sample. For women, the following subgroups had a higher HIV screening rate compared to the national women average of 13%: Those aged 25-29 years (19%) and 30-34years (19%), women currently married (16%), those with previous STI (16%), women with only one sexual partner (16%), from richest households (18%) and those with higher than secondary education (26%). The following men subgroups had HIV screening rate higher than the national average of 6%: those aged 35-39years 11%, higher than secondary education (18%) and richest household (10%). Chi-square test of association showed that the following variables were significantly associated with HIV testing in both the women and men samples: age, education, marital status, religious affiliation, number of sexual partners within the last 12 months preceding the survey (wife/husband inclusive), wealth index, and the place and region of residence ($p < 0.05$). History of sexually transmitted infection (STI) in the last 12 months

was significantly associated with HIV testing in only the women sample in bivariate analysis.
(Table 1).

Table 1: summary statistics of study variables

	HIV test in the past 12 months (%)					
	Women			Men		
	Total	No	Yes	Total	No	Yes
	9380(100)	87	13	3854 (100)	94	6
Age	p< 0.0001			p< 0.0001		
15-19	1622 (17)	96	4	852 (22)	99	1
20-24	1609 (17)	85	15	586 (15)	96	4
25-29	1603 (17)	81	19	586 (15)	92	8
30-34	1368 (15)	81	19	550 (14)	92	8
35-39	1295 (14)	85	15	472 (12)	89	11
40-44	1028 (11)	92	8	455 (12)	93	7
45-49	855 (9)	95	5	353 (9)	93	7
Education	p< 0.0001			p< 0.0001		
None	1790 (19)	91	9	361 (9)	97	3
Primary	1668 (18)	91	9	541 (14)	97	3
Secondary	5326 (57)	86	14	2505 (65)	95	5
Higher	596 (6)	74	26	446 (12)	82	18
Marital Status	p< 0.0001			p=0.001		
Never in union	3089 (33)	92	8	1844 (48)	96	4
Currently married	5311 (57)	84	16	1839 (48)	92	8
Previously Married	980 (10)	91	8	171 (4)	92	8
Religion	p< 0.0001			p< 0.0001		
Catholic	940 (10)	88	12	414 (11)	92	8
Protestants	1311 (14)	85	15	502 (13)	91	9
Pentecostal/Charismatic	3851 (41)	87	13	1213 (31)	95	5
Other Christians	1415 (15)	86	14	692 (18)	94	6
Islam	1420 (15)	88	12	677 (18)	95	5
Traditionalist	188 (2)	93	7	128 (3)	96	4
No religion	253 (3)	92	8	228 (6)	93	7
Sexual Partners	p< 0.0001			p< 0.0001		
None	2695 (29)	94	6	1154 (30)	97	3
One Partner	6566 (70)	84	16	2155 (56)	93	7
Two or more	119 (1)	89	11	546 (14)	92	8
Had STI	p= 0.001			p=0.577		
No	8958 (95)	87	13	3671 (95)	94	6
Yes	422 (5)	84	16	183 (5)	95	5
Household wealth Index	p< 0.0001			p< 0.0001		
Poorest	1509 (16)	93	7	636 (17)	98	2
Poorer	1634 (17)	90	10	646 (17)	96	4

Middle	1933 (21)	88	12	768 (20)	96	4
Richer	2113 (23)	86	14	845 (22)	93	7
Richest	2191 (23)	82	18	959 (25)	90	10
Urban-Rural residence	p< 0.0001			p< 0.0001		
Urban	5043 (54)	85	15	2042 (53)	92	8
Rural	4337 (46)	90	10	1812 (47)	96	4
Region of residence	p< 0.0001			p< 0.0001		
Western	1038 (11)	88	12	446 (12)	95	5
Central	935 (10)	86	14	379 (10)	96	4
Greater Accra	1897 (20)	85	15	828 (21)	91	9
Volta	720 (8)	87	13	293 (8)	94	6
Eastern	875 (9)	84	16	361 (9)	92	8
Ashanti	1793 (19)	88	12	678 (18)	94	6
Brong Ahafo	765 (8)	88	12	319 (8)	96	4
Northern	785 (8)	92	8	315 (8)	96	4
Upper East	358 (4)	89	11	145 (4)	91	9
Upper West	214 (2)	88	12	90 (2)	96	4

Effect modification of gender on the relationship between each sociodemographic variable and HIV testing in Ghana

Gender was found to be a significant effect modifier on the relationship between HIV testing and all the sociodemographic variables under investigation : age ($p < 0.001$), marital status ($p < 0.001$), household wealth index ($p < 0.001$), educational level ($p < 0.001$), type of religion ($p < 0.001$), total number of sexual partners in the past 12 months ($p < 0.001$), STI status in the past 12 months ($p < 0.001$), place of residence ($p < 0.001$), and region of residence ($p < 0.001$) S1 Table.

Gender variations in the strength of association between HIV testing and sociodemographic factors

Regressors that were important to building a statistical model to explain the variability in HIV testing were somewhat different for women and men. For the women model, seven variables were identified as the appropriate correlate of HIV testing: age, education, marital status, sexual partners in the past 12 months, diagnosed with an STI in the past 12 months, household wealth, and region of residence (S1 Table, Figure 1). For the men model, six regressors were identified:

age, education, religion, sexual partners in the past 12 months, urban-rural residence, and region of residence (S1 Table, Figure 2).

These four factors are consistent correlates of HIV testing for both women and men: age, education, sexual partners in the past 12 months, and region of residence (S1 Table, Figure 1 & 2). These consistent factors were first interpreted before the interpretation of the men or women model-specific correlates. Although the direction of the association was generally the same for most variables in both women and men, the strength of the association varied by gender in some instances.

Relative to women aged 15-19years, the likelihood of HIV testing was about 2.1 times greater among their counterparts aged 20-24years [APR:2.107, 95% CI: 1.513, 2.935]. A similar pattern was observed for other older age groups 25-29yrs, 30-34yrs, 35-39yrs but not for women aged 40-44yrs, and 45-49years (S1 Table, Figure 1). Unlike the women counterparts, men in the older quinary age groups had a higher likelihood of HIV testing relative to their counterparts aged 15-19years. The magnitude of the effect was also greater in men compared to women (S1 Table, Figure 2).

Compared to women with no formal education, those with higher than secondary education had a 2.0 times greater likelihood of undergoing HIV screening [APR:2.026, 95% CI:1.510, 2.719] (S1 Table, Figure 1). A similar observation was made in the men sample but with a higher magnitude [APR:5.735, 95% CI:2.464, 13.35] (S1 Table, Figure 2). Women who had attained secondary education were 1.3 times likely to have undergone HIV screening compared to their counterparts with no formal education [APR:1.370, 95% CI:1.083, 1.731] (S1 Table, Figure 1). However, attainment of secondary school education was not a significant protective factor of HIV testing among men (S1 Table, Figure 2).

Women with only one sexual partner within the last 12 months were 1.5 times likely to have undergone HIV screening compared to their counterparts who had no sexual partners [APR:1.565, 95% CI:1.193,2.052] (S1 Table, Figure 1). However, this segment of the men population was not significantly associated with HIV testing among men (S1 Table, Figure 2).

Significant regional variations were observed in HIV testing among women and men. Residing in three regions was significantly associated with HIV testing compared to the greater Accra region among women, but only one region was significantly associated with the outcome among men in the same circumstances (S1 Table, Figure 1 & 2). For instance, compared to women living in the Greater Accra Region, those living in the Volta (APR: 1.282, 95% CI: 1.015, 1.619), Eastern [APR:1.338, 95% CI: 1.048,1.710], Upper East [APR:1.571, 95% CI: 1.096,2.253] and Upper West [APR:1.478, 95% CI:1.059, 2.062] regions had a higher likelihood of testing and receiving their HIV results (S1 Table, Figure 1). In the men sample, men living in the Upper East region had a 2.1 times higher likelihood of undergoing HIV screening [APR:2.188, 95%CI: 1.187, 4.032] compared to their counterparts in the Greater Accra Region (S1 Table, Figure 2).

Women who were currently married were 1.8 times likely to have undergone HIV screening compared to their counterparts who have never been in union [APR:1.855, 95%CI:1.487, 2.313] (S1 Table, Figure 1). The history of STI was not found to be an independent predictor of HIV screening in the women sample. Relative to the women in the poorest wealth quintiles, their counterparts who were in the poorer [APR:1.548, 95% CI:1.126, 2.128], middle [APR:1.724, 95% CI:1.259, 2.360], richer [APR:1.930, 95% CI:1.406, 2.648] and richest [2.190, 95%CI: 1.570, 3.056] wealth quintiles were more likely to have undergone HIV screening in the last 12years (S1 Table, Figure 1). Religion and urban-rural residence, although were identified as

important features of HIV testing among men, were not significantly associated with HIV testing in the men model (S1 Table, Figure 2).

HIV testing prevalence in Ghana estimated by kernel estimator approach

Figure 3 shows the Ghana map (generated by the authors in QGIS version 3.10) with the ten regional demarcations and labels to facilitate the interpretation of the surface maps (Figure 3). Overall, the HIV testing surface maps for both women and men samples revealed that the national and regional level estimates mask sub-regional level variations in HIV testing (Figure 4 & 5). The general observation for the surface maps of the women sample is that the areas with the highest HIV testing prevalence are in the southern regions while the lowest prevalence is found in the northern part of the country (Figure 4). These regions in southern Ghana include the Eastern, Greater Accra, Western, Eastern, and Volta. There are, however, areas in Upper East and West regions with relatively high HIV prevalence although the adjoining areas had low screening rate [the Northern region]. For the men surface map, there were areas of high testing prevalence in southern Ghana including the adjoining areas of Eastern, Greater Accra and Volta region in the surface maps of the men sample. It also showed a high screening rate among men in some clusters in the Ashanti and Upper East Regions (Figure 5). In summary, the surface maps showed inter-regional and intra-regional disparities in HIV screening rate in both the men and women sample. For instance, there are areas within each region with higher testing prevalence than others.

Discussion

This study conducted a multivariate analysis and spatial interpolation of the predictors of HIV testing in Ghana using nationally representative data, GDHS. To the authors’ knowledge, this is

the first study to analyse factors that influence recent HIV test prevalence in Ghana together with spatial interpolation using the GDHS, stratified by gender. We found that the prevalence of HIV testing was higher among women (13%) than men (6%). Our results have shown that sex, age, education level, marital status, total sexual partners in the past 12 months, household wealth index and region of residence were significantly associated with HIV testing among women and/or men. For women, being within the age groups of 15-39 years, being currently married, attainment of post-secondary education, having only one sexual partner, and dwelling in certain regions with reference to greater Accra (Volta, Eastern, Upper West, and Upper East) were associated with a higher likelihood of HIV testing. For men, being older than 19 years, attainment of post-secondary education and dwelling in the Upper East region with reference to the greater Accra region were significantly associated with a higher likelihood of HIV testing.

The recent HIV testing prevalence found in our study was generally lower compared to estimates reported in Sierra Leone, Zambia, Lesotho, and Zimbabwe.²² All the countries with high rates of HIV testing are located in southern Africa and the high rates of testing in these countries were attributed to high rates of HIV prevalence, mandatory HIV testing at prenatal clinics and mobile clinics for HIV testing to mitigate the high prevalence of the virus.²²

There are some suggestive reasons for the relatively high HIV testing in Eastern, Greater Accra, and Central among both women and men in Ghana. The district—Lower Manya Krobo—that continually records the highest HIV prevalence in Ghana is in the Eastern region with a current estimate of 5.56% HIV prevalence.²³ Therefore, HIV reduction programs by government and non-governmental organizations (NGOs) are concentrated in the Eastern region.²⁴ HIV testing could be a proxy for access to healthcare facilities. Since the Greater Accra is the region with the highest number of healthcare facilities in Ghana, more people in the region may find it

easy to screen for HIV.^{24 25} Our spatial interpolation revealed that there are areas in Ghana with higher HIV testing prevalence compared to the national and regional estimates. For example, in the Western Region, regional HIV testing prevalence was 12%, however, the spatial interpolation identified some clusters to be as low as 5% and some as high as 30%. These within region variations underscore the importance of applying spatial interpolation in population-based studies to unmask the hidden details which can help design targeted interventions.

Women, in general, had a greater likelihood of HIV testing compared to their men counterparts, although below the national and global 90-90-90 targets, this is in agreement with previous studies.^{11 26} This can partly be explained by the fact that HIV testing for women during prenatal care which aims at reducing mother-to-child transmission of HIV.^{27 28} We found that compared to all age groups, adolescents between ages 15 and 19 years tend to have the lowest likelihood of getting tested for HIV. This finding is critical to public health because earlier studies have reported that higher rates of HIV infection among adolescents are more likely due to being engaged in risky behaviour and unsafe sex practices which put them at risk of contracting HIV.^{29 30} Therefore, health policymakers should target adolescents with health education and mass HIV testing programs and interventions. In Ghana, health testing such as breast cancer testing among older adult women has been reported to be associated with participation in club meetings.³¹ Given that many youth clubs exist in Ghana, they could be encouraged and incentivised to add HIV testing to their club activities.

Our results showed that educational status was a significant predictor of HIV testing among both women and men. People with higher education may have adequate knowledge and understanding of the implications of testing for HIV, thereby resulting in their likelihood to

patronize testing services. Our finding concurs with previous studies,^{32 33} that reported a positive relationship between education and HIV testing.

We found that women who were currently married were more likely to be tested than those who have never married. For men, marital status was not significantly associated with HIV testing. Generally, in most African countries including Ghana, religious institutions and local governments require mandatory pre-marital HIV testing as a means to combat the spread of HIV among newly married couples.^{34 35} Therefore, married people have the possibility of being tested for HIV compared to their unmarried counterparts. Although contentious and said to be a source of stigmatization and human right violation to those who test HIV positive,^{34 36 37} mandatory pre-marital HIV testing is said to be an effective way of people knowing their status. Therefore, there is a need for collaboration between public health officials and other leaders such as religious and community leaders to partner to help improve HIV testing in the communities.

Unlike men, current marriage among women was significantly associated with an increased likelihood of HIV testing. This observation can be explained by the fact that sexual activities and childbirth are socially acceptable among married couples in Ghana.³⁸ For most women, marriage sometimes results in childbirth and HIV testing is done for all women who visit antenatal as part of the prevention of mother to child transmission policy in Ghana.³⁹ This service is generally exclusive for pregnant women and does not apply to men. For currently married men, an HIV test is not required even if their wives attend antenatal care services. To encourage men to test for HIV, it is important that HIV testing is made compulsory for husbands or partners of women attending antenatal care.

Our findings also highlighted some noteworthy variations in the factors associated with HIV testing between men and women. Primary education was significantly and independently

associated with an increased likelihood of HIV testing in women and men, but the effect was greater for men than women. This finding is important because it reinforces the health value of universal basic education in Ghana and the need to encourage women to attain universal basic education for improved health outcomes. Also, the magnitude of the effect of increasing age on HIV testing was generally larger for men than women. Moreover, men in age groups 40-49yrs had a significantly higher likelihood of having undergone HIV testing compared to men aged 15-19 years but women in these age brackets were not significantly associated with HIV testing. This can be partly explained by the fact that most women aged 45-49 might have reached menopause and their engagement in active sexual activities might have reduced⁴⁰ and hence were probably not targeted for HIV testing by a public health professional. On the contrary, their men counterparts are generally sexually active and were more likely to have been targeted for HIV testing by public health professionals.⁴¹ We also found that women who had one sexual partner in the past 12 months were significantly more likely to undergo HIV testing, but this association was absent among men.

Another noteworthy gender variation was observed for the effect of household wealth on HIV testing. We found that wealth status predicts the likelihood of HIV testing among Ghanaian women only. Compared to the women from the poorest household, we found a higher likelihood for HIV testing among women in the poorer, middle, richer, and richest households. This finding is consistent with previous studies.^{32 37 42} The cost associated with the testing could be a barrier for people with low socioeconomic status to get tested. These findings suggest the need for sensitization campaigns targeting communities and people with a low level of education and socioeconomic status to increase their awareness of the importance of HIV testing. This could be done through targeted outreach such as mobile clinics and integrating HIV testing into routine

healthcare services, improving home-based and self-testing, and subsidising the cost of the testing. Community leaders such as chiefs and religious leaders should also be involved in promoting HIV testing. This finding implies that any policy which can increase the economic standings of households, no matter how small the change may be, has a benefit on health care utilization as far as HIV testing, especially for women. This finding is similar to a study conducted among the same population in Mozambique using the DHS dataset.³⁷

Strength and Limitation

The current study used a large, nationally representative survey data set and employed a robust methodology for analyses. We stratified our analysis by gender which revealed interesting findings which can guide policy to target each gender to ensure efficiency and effectiveness of policy interventions. We employed spatial interpolation techniques that have advantages over standard statistical techniques to identify geographical variations of HIV testing prevalence in Ghana. This may be of population health significance in the effort to meet the UNAIDS 90-90-90 target not only in Ghana but in other sub-Saharan African countries. Cluster analysis with the Scan Statistics method adjusts for population density and decreases selection bias as the clusters are explored without previous knowledge of their size, location or period.⁴³ Furthermore, our study uncovered the population that is most at risk of not being tested for HIV and geographical locations with low HIV testing in Ghana. These findings could serve as a framework for public health officials to design targeted intervention to increase HIV testing.

Our findings, however, are subject to limitations that must be taken into consideration. As characteristics of all cross-sectional studies, our study could neither establish temporality nor causality of the observed association. It is important to note that all the variables in this study were self-reported and this could have introduced recall or social desirability bias. Also, we were

not able to ascertain the actual reasons for participant’s prior HIV testing and therefore this was not accounted for in our analysis. Moreover, a limitation with the visualization of HIV testing using spatial maps is that the testing rate is dispersed across all pixels regardless of the presence or absence of population settlements. Despite these limitations, this study has provided profound insights from a population-level survey analysis as well as a spatial analysis of HIV testing prevalence in Ghana for informed public health action.

Conclusion

In conclusion, the study findings could help public health officials to better understand factors associated with HIV testing among the Ghanaian general population by showing the areas and at risk-population for targeted HIV intervention programs. We found that 13% of women and 6% men of in the population in Ghana have ever been screened for HIV. The highest regional HIV testing prevalence was recorded in the Eastern region (16%) and that of men was recorded in the Greater Accra region (9%). The spatial interpolated prevalence map further revealed intraregional level differences in HIV testing estimates. We also found gender variations in the factors associated with HIV testing which could guide policy interventions. Expansion of HIV testing, outreach through mobile clinics, home-based and self-testing, wide-ranging coverage through outreach programs, community-based approaches, and integration of opportunities or HIV testing during regular medical care is critical. These myriad approaches will be integral in reaching all persons with sub-clinical HIV infections in sub-Saharan Africa for life-saving treatment.

Figure Legends:

Figure 1: Coefficient plot showing the correlates of HIV testing among Ghanaian women

Figure 2: Coefficient plot showing the correlates of HIV testing among Ghanaian men

Figure 3: Ghana map showing the regional demarcation and label

Figure 4: HIV testing prevalence among women in Ghana estimated by kernel estimator approach

Figure 5: HIV testing prevalence among men in Ghana estimated by kernel estimator approach

Conflict of Interest

The authors declare that they have no competing interests.

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Data availability statement

The 2014 GDHS data are publicly available upon a simple registration-access request so data used for this study can be obtained from the DHS website at https://dhsprogram.com/data/dataset_admin/index.cfm.

Authors' contributions

All authors contributed to the design of the study. JJN obtained permission and downloaded datasets from the DHS program website, and contributed to the drafting and review of the manuscript. HOD and PA contributed to the analysis of data and drafting of the manuscript. PAD, RKA and ED participated in the drafting of the manuscript. All authors critically reviewed the manuscript and approved the final version.

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References

1. World Health Organization. HIV/AIDS: Data and Statistics 2018 [cited 2019. Available from: <https://www.who.int/hiv/data/en/> accessed August 10, 2019.

2. UNAIDS. Global HIV & AIDS statistics — 2019 fact sheet 2019 [cited 2020 June 20]. Available from: <https://www.unaids.org/en/resources/fact-sheet> accessed June 16 2020.

3. World Health Organization. HIV/AIDS Fact Sheet Geneva: World Health Organization 2019 [updated November 15, 2019]. Available from: <https://www.who.int/en/news-room/fact-sheets/detail/hiv-aids> accessed November 25 2019.

4. Kharsany AB, Karim QA. HIV infection and AIDS in sub-Saharan Africa: current status, challenges and opportunities. *The open AIDS journal* 2016;10:34.

5. Narin P, Yamamoto E, Saw YM, et al. Factors associated with HIV testing among the general male population in Cambodia: A secondary data analysis of the Demographic Health Survey in 2005, 2010, and 2014. *PloS one* 2019;14(7):e0219820.

6. UNAIDS. AIDS JUNPo: 90–90–90: an ambitious treatment target to help end the AIDS epidemic. Geneva: UNAIDS 2014

7. Asamoah CK, Asamoah BO, Agardh A. A generation at risk: A cross-sectional study on HIV/AIDS knowledge, exposure to mass media, and stigmatizing behaviors among young women aged 15–24 years in Ghana. *Global health action* 2017;10(1):1331538.

8. Gómez-Ayerbe C, Martínez-Sanz J, Muriel A, et al. Impact of a structured HIV testing program in a hospital emergency department and a primary care center. *PloS one* 2019;14(8):e0220375.

9. Koku EF. Stigma, sexual risk and desire for HIV tests in Ghana. *Sexual health* 2011;8(1):110-19.

10. Laar A, DeBruin D. Key populations and human rights in the context of HIV services rendition in Ghana. *BMC International Health and Human Rights* 2017;17(1):1-10.

11. Ali H, Amoyaw F, Baden D, et al. Ghana’s HIV epidemic and PEPFAR’s contribution towards epidemic control. *Ghana medical journal* 2019;53(1):59-62.

12. Addo SA, Abdulai M, Yawson A, et al. Availability of HIV services along the continuum of HIV testing, care and treatment in Ghana. *BMC Health Services Research* 2018;18(1):739.

13. Van Hulst M, Sagoe KW, Vermande JE, et al. Cost-effectiveness of HIV screening of blood donations in Accra (Ghana). *Value in Health* 2008;11(5):809-19.

14. John Nutor J, Duodu PA, Agbadi P, et al. Predictors of high HIV+ prevalence in Mozambique: A complex samples logistic regression modeling and spatial mapping approaches. *Plos one* 2020;15(6):e0234034.

15. Osei-Yeboah J, Lokpo SY, Ussher FA, et al. The Epidemiology of Human Immunodeficiency Virus (HIV) and Syphilis in Ghana: A Five-Year Single Urban Site Parallel Population-Based Analysis vis-à-vis the Sentinel Survey. *Journal of tropical medicine* 2018;2018

16. GSS G. Ghana statistical service (GSS), Ghana health service (GHS), and ICF macro. Accra: Ghana Demogr Health Surv 2009;2008:79-96.

17. Lindsey C, Sheather S. Best subsets variable selection in nonnormal regression models. *The Stata Journal* 2015;15(4):1046-59.

18. Furnival GM, Wilson RW. Regressions by leaps and bounds. *Technometrics* 2000;42(1):69-79.

19. Lawless J, Singhal K. Efficient screening of nonnormal regression models. *Biometrics* 1978:318-27.

20. Larmarange J, Vallo R, Yaro S, et al. Methods for mapping regional trends of HIV prevalence from Demographic and Health Surveys (DHS). *Cybergeog: European Journal of Geography* 2011

21. Team RC. R: A language and environment for statistical computing. 2013

22. Staveteig S, Croft TN, Kampa KT, et al. Reaching the 'first 90': Gaps in coverage of HIV testing among people living with HIV in 16 African countries. *PLoS One* 2017;12(10):e0186316. doi: 10.1371/journal.pone.0186316 [published Online First: 2017/10/13]

23. Ghana AIDS Commission. National HIV and AIDS Policy: Universal Access to HIV Prevention, Treatment and Care Services towards Ending AIDS as a Public Health Threat. Accra, Ghana. 2019 [cited 2020 July 1]. Available from: [https://www.ghanais.gov.gh/mcadmin/Uploads/nationalHIVandAIDSPolicy\(2\).pdf](https://www.ghanais.gov.gh/mcadmin/Uploads/nationalHIVandAIDSPolicy(2).pdf) accessed July 1 2020.
24. Hushie M. Public-non-governmental organisation partnerships for health: an exploratory study with case studies from recent Ghanaian experience. *BMC Public Health* 2016;16(1):963.
25. Tun W, Okal J, Schenk K, et al. Limited accessibility to HIV services for persons with disabilities living with HIV in Ghana, Uganda and Zambia. *Journal of the International AIDS Society* 2016;19:20829.
26. Sanga Z, Kapanda G, Msuya S, et al. Factors influencing the uptake of Voluntary HIV Counseling and Testing among secondary school students in Arusha City, Tanzania: a cross sectional study. *BMC Public Health* 2015;15(1):452.
27. Nyuzaghl J, Ohene S, Odoi-Agyarko K. Acceptability of routine offer of HIV Testing (opt-out approach) among pregnant women in the Wa municipality. *Ghana medical journal* 2011;45(1)
28. Camlin CS, Ssemmondo E, Chamie G, et al. Men "missing" from population-based HIV testing: insights from qualitative research. *AIDS Care* 2016;28 Suppl 3(Suppl 3):67-73. doi: 10.1080/09540121.2016.1164806 [published Online First: 2016/07/16]
29. Dellar RC, Dlamini S, Karim QA. Adolescent girls and young women: key populations for HIV epidemic control. *Journal of the International AIDS Society* 2015;18:19408.
30. Kim YK, Small E, Okumu M. School-based HIV/AIDS education, risky sexual behaviors, and HIV testing among high school students in the United States. *Soc Work Health Care* 2019;58(3):258-73. doi: 10.1080/00981389.2018.1558163 [published Online First: 2018/12/18]
31. Agyemang AF, Tei-Muno AN, Dzomeku VM, et al. The prevalence and predictive factors of breast cancer screening among older Ghanaian women. *Heliyon* 2020;6(4):e03838.
32. Lépine A, Terris-Prestholt F, Vickerman P. Determinants of HIV testing among Nigerian couples: a multilevel modelling approach. *Health policy and planning* 2015;30(5):579-92.
33. Mirandola M, Gios L, Joanna Davis R, et al. Socio-demographic factors predicting HIV test seeking behaviour among MSM in 6 EU cities. *The European Journal of Public Health* 2017;27(2):313-18.
34. Akoku DA, Tihnje MA, Tarh EO, et al. Predictors of willingness to accept pre-marital HIV testing and intention to sero-sort marital partners; risks and consequences: Findings from a population-based study in Cameroon. *PloS one* 2018;13(12):e0208890.
35. Barmania S, Aljunid SM. Premarital HIV testing in Malaysia: a qualitative exploratory study on the views of major stakeholders involved in HIV prevention. *BMC international health and human rights* 2017;17(1):1-10.
36. Ifemeje S. Mandatory premarital HIV testing policy in Nigeria: a gross violation of the rights of people living with HIV/AIDS. *The International Journal of Human Rights* 2012;16(3):401-10.
37. Agbadi P, Nutor JJ, Darkwah E, et al. Covariates and Spatial Interpolation of HIV Screening in Mozambique: Insight from the 2015 AIDS Indicator Survey. *International Journal of Environmental Research and Public Health* 2020;17(16):5630.
38. Elleamoh GE, Dake FA. "Cementing" marriages through childbearing in subsequent unions: Insights into fertility differentials among first-time married and remarried women in Ghana. *PloS one* 2019;14(10):e0222994.
39. Ejigu Y, Tadesse B. HIV testing during pregnancy for prevention of mother-to-child transmission of HIV in Ethiopia. *PLoS One* 2018;13(8):e0201886. doi: 10.1371/journal.pone.0201886 [published Online First: 2018/08/10]
40. Krasnow SS, Maglio A-S. Female sexual desire: what helps, what hinders, and what women want. *Sexual and Relationship Therapy* 2019:1-29.

41. Gewirtz-Meydan A, Ayalon L. Why do older adults have sex? Approach and avoidance sexual motives among older women and men. *The Journal of Sex Research* 2019;56(7):870-81.

42. Agha S. Factors associated with HIV testing and condom use in Mozambique: implications for programs. *Reproductive Health* 2012;9(1):20.

43. Chimoyi LA, Musenge E. Spatial analysis of factors associated with HIV infection among young people in Uganda, 2011. *BMC public health* 2014;14(1):555.

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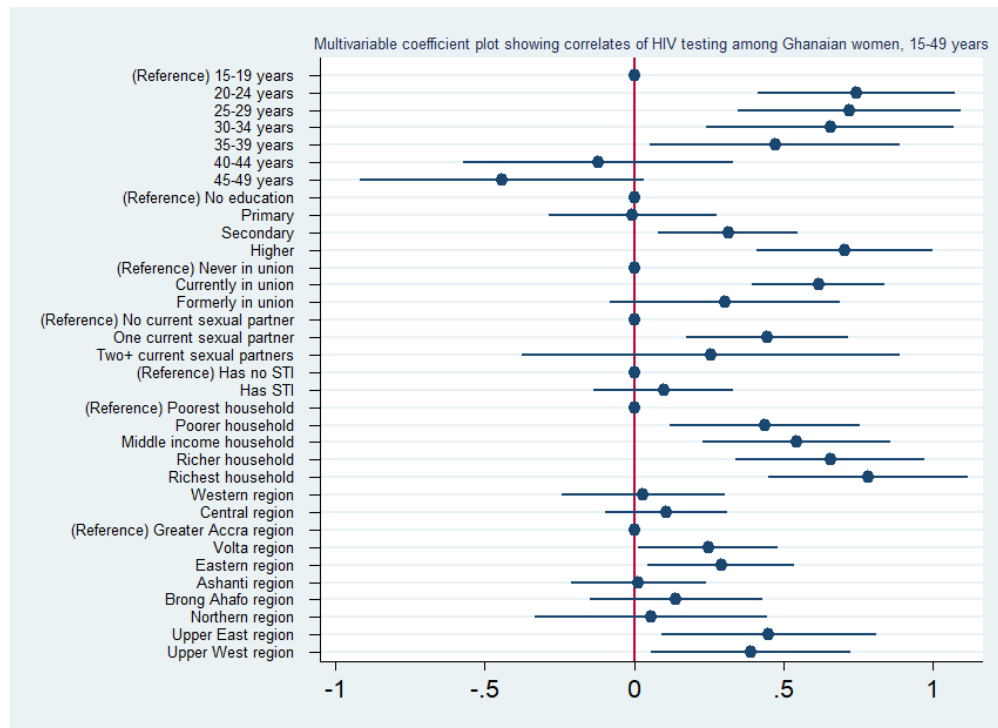


Figure 1: Coefficient plot showing the correlates of HIV testing among Ghanaian women

300x218mm (72 x 72 DPI)

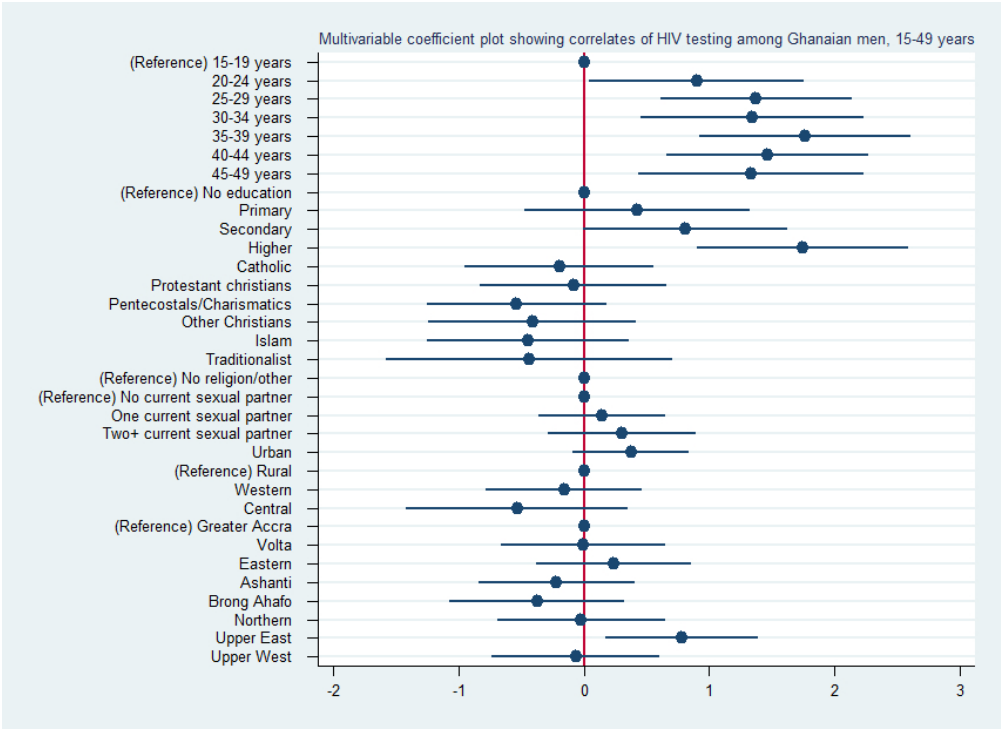


Figure 2: Coefficient plot showing the correlates of HIV testing among Ghanaian men

300x218mm (72 x 72 DPI)



Figure 3: Ghana map showing the regional demarcation and label

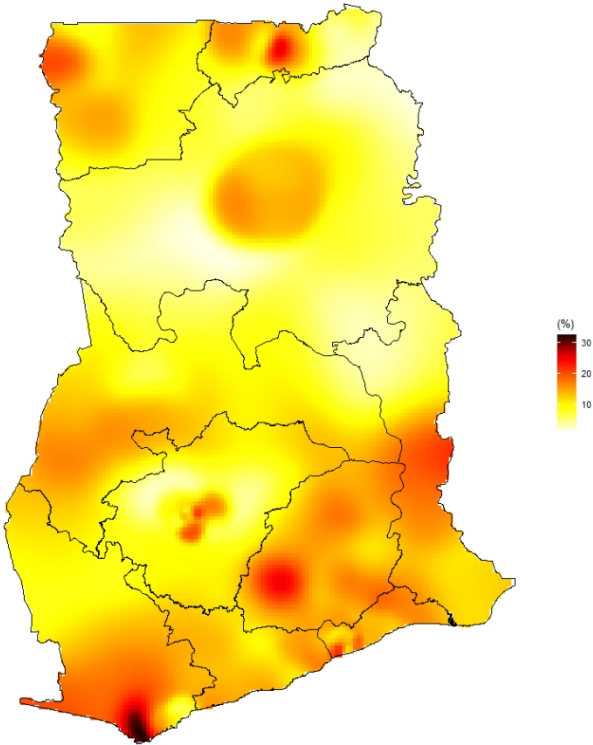


Figure 4: HIV testing prevalence among women in Ghana estimated by kernel estimator approach
317x264mm (96 x 96 DPI)

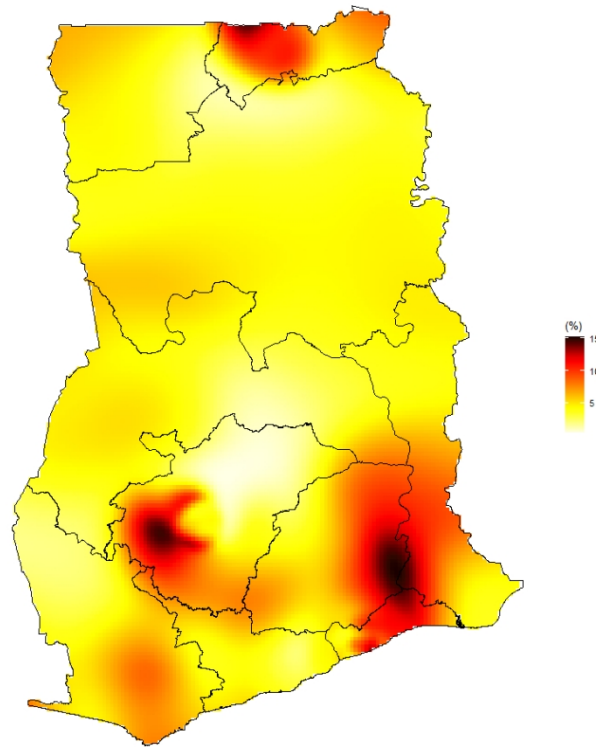


Figure 5: HIV testing prevalence among men in Ghana estimated by kernel estimator approach

317x264mm (96 x 96 DPI)

Supplementary table

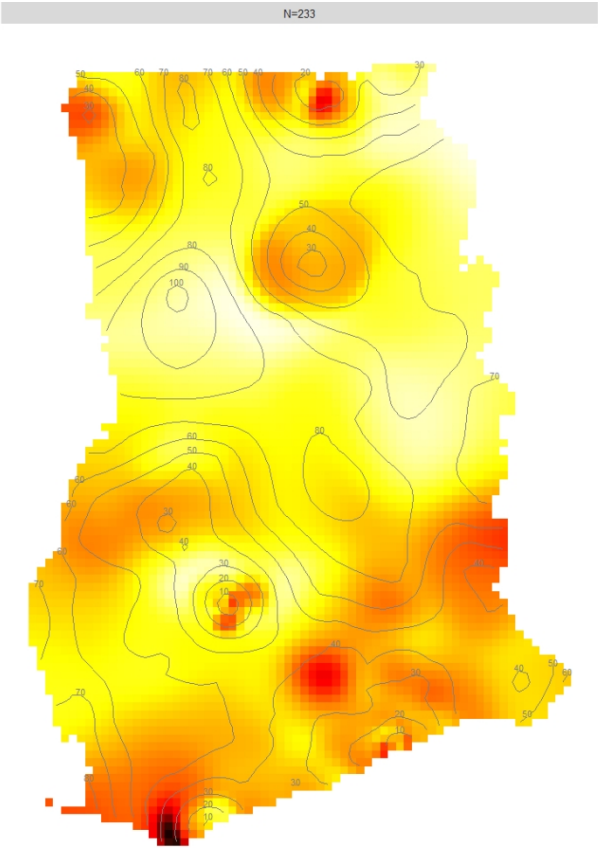
S1 Table: The Correlates of HIV testing in the last 12 months, stratified by gender

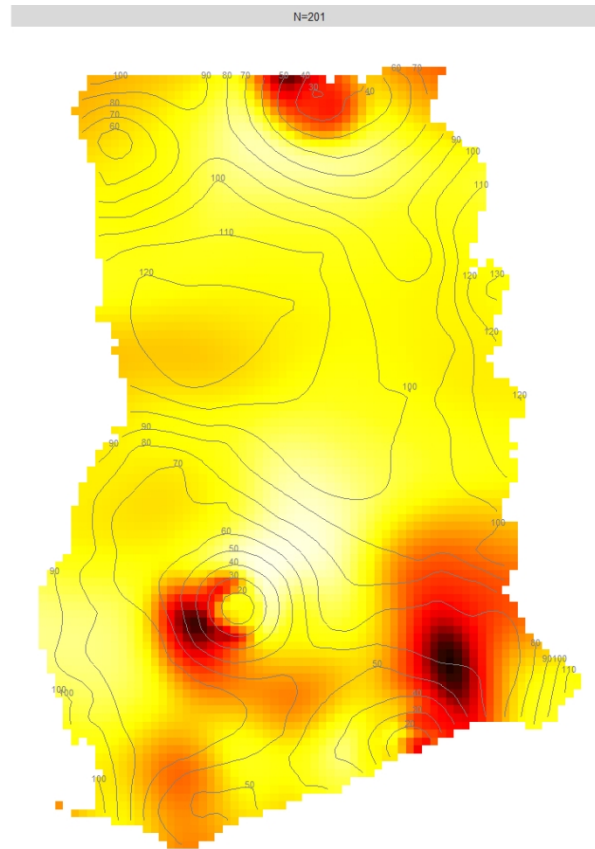
	Women		Men		adjusted Wald Test
	APR [95% CI]	APR [95% CI]	APR [95% CI]	APR [95% CI]	
Age	p< 0.0001	p< 0.0001	P=0.0036	P=0.0005	p< 0.0001
15-19	Ref	Ref	Ref	Ref	
20-24	2.112*** [1.517,2.941]	2.107*** [1.513,2.935]	2.428* [1.034,5.703]	2.459* [1.040,5.812]	
25-29	2.059*** [1.418,2.991]	2.057*** [1.418,2.986]	3.915*** [1.830,8.373]	3.955*** [1.840,8.503]	
30-34	1.930** [1.273,2.925]	1.929** [1.275,2.919]	3.846** [1.567,9.440]	3.841** [1.581,9.331]	
35-39	1.599* [1.052,2.431]	1.604* [1.054,2.439]	5.750*** [2.340,14.13]	5.855*** [2.519,13.61]	
40-44	0.886 [0.562,1.395]	0.887 [0.564,1.396]	4.233** [1.794,9.986]	4.335*** [1.938,9.696]	
45-49	0.637 [0.395,1.029]	0.642 [0.399,1.033]	3.792** [1.498,9.600]	3.812** [1.549,9.385]	
Education	p< 0.0001	p< 0.0001	P=0.0001	p< 0.0001	p< 0.0001
None	Ref	Ref	Ref	Ref	
Primary	0.997 [0.759,1.310]	0.994 [0.751,1.317]	1.408 [0.561,3.529]	1.527 [0.622,3.749]	
Secondary	1.378** [1.105,1.718]	1.370** [1.083,1.731]	1.783 [0.758,4.199]	2.246 [0.996,5.064]	
Higher	2.064*** [1.560,2.731]	2.026*** [1.510,2.719]	3.978** [1.594,9.930]	5.735*** [2.464,13.35]	
Marital Status	p< 0.0001	p< 0.0001	P=0.9405		p< 0.0001

Never in union	Ref	Ref	Ref	Ref	
Currently married	1.881*** [1.507,2.349]	1.855*** [1.487,2.313]	0.926 [0.603,1.423]	--	
Previously Married	1.366 [0.932,2.001]	1.354 [0.921,1.991]	0.937 [0.447,1.967]	--	
Religion	P=0.6894		P=0.3851	P=0.4188	p< 0.0001
Catholic	1.141 [0.708,1.841]		0.741 [0.350,1.570]	0.823 [0.387,1.750]	
Protestants	1.349 [0.853,2.132]	--	0.839 [0.397,1.774]	0.921 [0.438,1.935]	
Pentecostal/Charismatic	1.222 [0.780,1.914]	--	0.533 [0.259,1.096]	0.585 [0.286,1.196]	
Other Christians	1.295 [0.801,2.094]	--	0.602 [0.263,1.378]	0.662 [0.289,1.513]	
Islam	1.312 [0.812,2.121]	--	0.583 [0.256,1.327]	0.641 [0.287,1.434]	
Traditionalist	1.101 [0.540,2.245]	--	0.718 [0.241,2.140]	0.647 [0.207,2.020]	
Ref	Ref	Ref	Ref	Ref	p< 0.0001
Sexual Partners	P=0.0052	P=0.0052	P=0.5687	P=0.5808	
None	Ref	Ref	Ref	Ref	
One Partner	1.566** [1.194,2.055]	1.565** [1.193,2.052]	1.185 [0.688,2.043]	1.156 [0.694,1.925]	
Two or more	1.299 [0.682,2.474]	1.292 [0.685,2.435]	1.394 [0.746,2.603]	1.359 [0.752,2.457]	
Had STI	P=0.4229	P=0.4091	P=0.2970		
No	Ref	Ref	Ref	Ref	p< 0.0001
Yes	1.100 [0.871,1.388]	1.103 [0.873,1.393]	0.706 [0.366,1.360]	--	

Household wealth Index	P=0.0306	P=0.0003	P=0.049		
Poorest	Ref	Ref	Ref	Ref	p< 0.0001
Poorer	1.479* [1.085,2.016]	1.548** [1.126,2.128]	2.309* [1.090,4.890]	--	
Middle	1.577** [1.146,2.169]	1.724*** [1.259,2.360]	1.894 [0.848,4.233]	--	
Richer	1.696** [1.188,2.422]	1.930*** [1.406,2.648]	3.283** [1.363,7.909]	--	
Richest	1.860** [1.268,2.729]	2.190*** [1.570,3.056]	3.410** [1.366,8.515]	--	
Urban-Rural residence	P=0.1997		P=0.8940	P=0.1147	p< 0.0001
Urban	1.137 [0.934,1.385]	--	1.039 [0.593,1.819]	1.455 [0.913,2.320]	
Rural	Ref	Ref	Ref	Ref	
Region of residence	P=0.0710	P=0.0759	P=0.0001	P=0.0123	p< 0.0001
Western	1.059 [0.809,1.387]	1.031 [0.784,1.356]	0.861 [0.470,1.578]	0.854 [0.458,1.592]	
Central	1.137 [0.925,1.398]	1.114 [0.909,1.365]	0.581 [0.235,1.437]	0.586 [0.242,1.420]	
Greater Accra	Ref	Ref	Ref	Ref	
Volta	1.317* [1.049,1.652]	1.282* [1.015,1.619]	1.153 [0.594,2.238]	0.995 [0.518,1.910]	
Eastern	1.339* [1.048,1.710]	1.338* [1.048,1.710]	1.393 [0.759,2.556]	1.270 [0.687,2.348]	
Ashanti	1.023 [0.816,1.283]	1.015 [0.809,1.273]	0.810 [0.440,1.491]	0.803 [0.430,1.500]	
Brong Ahafo	1.129 [0.848,1.501]	1.151 [0.863,1.536]	0.814 [0.409,1.619]	0.687 [0.342,1.383]	

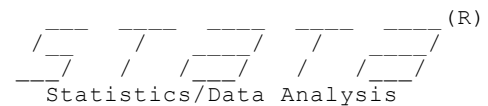
Northern	1.036 [0.699,1.537]	1.059 [0.718,1.563]	1.321 [0.707,2.469]	0.980 [0.504,1.908]	
Upper East	1.542* [1.060,2.242]	1.571* [1.096,2.253]	3.522*** [1.868,6.641]	2.188* [1.187,4.032]	
Upper West	1.480* [1.039,2.109]	1.478* [1.059,2.062]	1.166 [0.584,2.330]	0.937 [0.478,1.835]	
model details					
Strata	20	20	20	20	
PSUs	427	427	426	426	
Observations	9380	9380	3854	3854	
Population size	9381.3827	9381.3827	3868.3305	3868.3305	
Design df	407	407	406	406	
F	(34, 374) = 13.75	(27, 381) = 17.15	(34, 373) = 5.22	(27, 380) = 5.79	
Prob > F	< 0.00001	< 0.00001	< 0.00001	< 0.00001	
AIC	6991.539	6989.227	1698.33	1693.87	
Exponentiated coefficients; 95% confidence intervals in brackets					
* p<0.05, ** p<0.01, *** p<0.001					





```
1      Model Selection for Female HIV test   Friday April 9 01:47:30 2021   Page 1
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3
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5
6
7
8
9      1 . ***model selection
10     2 . gvselect <term> aaaV013 aaaV106 aaaV502 Religyn SexPart aaaV763A aaaV190 aaaV025 aaaV024: poisson
11
12     Optimal models:
13
14     # Preds      LL      AIC      BIC
15     1 -3593.924  7191.847  7206.14
16     2 -3537.579  7081.158  7102.597
17     3 -3519.462  7046.923  7075.508
18     4 -3506.324  7022.649  7058.38
19     5 -3493.142  6998.284  7041.162
20     6 -3487.799  6989.598  7039.623
21     7 -3486.613  6989.227  7046.397
22     8 -3486.113  6990.226  7054.543
23     9 -3485.769  6991.539  7063.002
24
25     predictors for each model:
26
27     1 : aaaV106
28     2 : SexPart aaaV106
29     3 : SexPart aaaV502 aaaV106
30     4 : SexPart aaaV502 aaaV106 aaaV013
31     5 : SexPart aaaV502 aaaV106 aaaV013 aaaV190
32     6 : SexPart aaaV502 aaaV106 aaaV013 aaaV190 aaaV024
33     7 : SexPart aaaV502 aaaV106 aaaV013 aaaV190 aaaV024 aaaV763A
34     8 : SexPart aaaV502 aaaV106 aaaV013 aaaV190 aaaV024 aaaV763A Religyn
35     9 : SexPart aaaV502 aaaV106 aaaV013 aaaV190 aaaV024 aaaV763A Religyn aaaV025
36
37     3 .
38     end of do-file
39
40     4 .
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Model Selection for Male HIV test Friday April 9 03:38:14 2021 Page 1



User: Pascal Agbadi

Project: HIV TEST IN LAST 12 MONTHS{space -4}

```
1 . ***model selection
2 . gvselect <term> aaaMV013 aaaMV106 aaaMV502 Religyn SexPart aaaMV763A aaaMV190 aaaMV025 aaaMV024:
532 observations containing missing predictor values
```

Optimal models:

#	Preds	LL	AIC	BIC
1		-873.6708	1751.342	1763.855
2		-856.861	1719.722	1738.493
3		-849.077	1706.154	1731.181
4		-845.0365	1700.073	1731.357
5		-841.0683	1694.137	1731.678
6		-839.9352	1693.87	1737.669
7		-839.2897	1694.579	1744.634
8		-839.2115	1696.423	1752.735
9		-839.1649	1698.33	1760.898

predictors for each model:

```
1 : aaaMV106
2 : aaaMV106 aaaMV013
3 : aaaMV106 aaaMV013 aaaMV025
4 : aaaMV106 aaaMV013 SexPart aaaMV025
5 : aaaMV106 aaaMV013 aaaMV024 SexPart aaaMV025
6 : aaaMV106 aaaMV013 aaaMV024 SexPart aaaMV025 Religyn
7 : aaaMV106 aaaMV013 aaaMV024 SexPart aaaMV025 Religyn aaaMV190
8 : aaaMV106 aaaMV013 aaaMV024 SexPart aaaMV025 Religyn aaaMV190 aaaMV763A
9 : aaaMV106 aaaMV013 aaaMV024 SexPart aaaMV025 Religyn aaaMV190 aaaMV763A aaaMV502
```

```
3 .
end of do-file
```

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*
Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(a) Cohort study—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants	7-8
		(b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed Case-control study—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	NA
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	7-10
		(b) Describe any methods used to examine subgroups and interactions	NA
		(c) Explain how missing data were addressed	8
		(d) Cohort study—If applicable, explain how loss to follow-up was addressed Case-control study—If applicable, explain how matching of cases and controls was addressed	9

		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	10-13
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	13-16
		(b) Report category boundaries when continuous variables were categorized	Na
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Na
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Na
Discussion			
Key results	18	Summarise key results with reference to study objectives	17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	21-22
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	21-22
Generalisability	21	Discuss the generalisability (external validity) of the study results	22
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	23

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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**Geographical variations and factors associated with recent HIV testing prevalence in
Ghana: spatial mapping and complex survey analyses of the 2014 demographic and health
surveys**

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Abstract

Objective: To examine the factors associated with recent HIV testing and to develop an HIV testing prevalence surface map using spatial interpolation techniques to identify geographical areas with low and high HIV testing rates in Ghana.

Design: Secondary analysis of Demographic and Health Survey (DHS)

Setting: Rural and urban Ghana

Participants: The study sample comprised 9380 women and 3854 men of 15 through 49 years.

Results: We found that 13% of women and 6% of men of Ghana had tested for HIV in the past 12 months. For women, being within the age groups of 15-39 years, being currently married, attainment of post-secondary education, having only one sexual partner, and dwelling in certain regions with reference to greater Accra (Volta, Eastern, Upper West, and Upper East) were associated with a higher likelihood of HIV testing. For men, being older than 19 years, attainment of post-secondary education and dwelling in the Upper East region with reference to the greater Accra region were significantly associated with a higher likelihood of HIV testing. The surface map further revealed intraregional level differences in HIV testing estimates.

Conclusion: Given the results, HIV testing must be expanded with equitable testing resource allocation that target areas within the regions in Ghana with low HIV testing prevalence. Men should be encouraged to be tested for HIV.

Keywords: HIV testing; Spatial Analysis; Complex Sample Design; HIV prevention

Strengths and limitations of this study

- This study used a large, nationally representative survey dataset that employed a robust methodology for analysis
- A large number of people in sub-Saharan Africa are unaware of their HIV status, thereby missing the opportunity for care and treatment
- There are limited studies on spatial analysis to reveal intraregional level differences in HIV testing in Ghana
- The cross-sectional design of this study precluded any causal inference
- HIV testing must be expanded with equitable testing resource allocation that target areas within the regions in Ghana with low HIV testing

Introduction

Despite the progress made in advancing knowledge and antiretroviral treatment, the human immunodeficiency virus (HIV) continues to cause a high number of deaths and morbidity globally.^{1 2} Globally, about 37.9 million people were living with HIV in 2018¹. Sub-Saharan Africa (SSA) alone accounts for over 70% of people living with HIV, although it is home to only about 12% of the global population.³ Testing programs may help to estimate the prevalence and predictors of the disease towards developing context-specific policy actions to combat the disease. However, a large number of people in SSA are unaware of their HIV status, thereby missing the opportunity for care and treatment.⁴

Knowing HIV status is the first and critical step towards eradicating AIDS.⁵ Therefore, the Joint United Nations Programme on HIV/AIDS (UNAIDS) set the “90-90-90 target” to be achieved by the end of 2020⁶. The target has called for 90% of people living with HIV are to be aware of their HIV status, 90% of those diagnosed with HIV to have access to antiretroviral therapy (ART), and 90% of those receiving ART to achieve suppression of the viral loads.⁶ Sadly, the well-established HIV prevention tools are few amidst the mitigating factors affecting the desire for and uptake of HIV testing such as stigma, and therefore early diagnosis and early ART needs to be prioritized.⁷⁻⁹ The limitation of the HIV testing-care-treatment continuum may adversely affect the achievement of the global “90-90-90” target.

In Ghana, HIV is epidemiologically described as mature, mixed, and generalised.¹⁰ Recent studies report HIV prevalence of about 1.6% among the general population.^{11 12} The epidemic is largely driven by heterosexual contact and mother-to-child transmission,¹³ and also varies among groups and geographical locations.^{11 14} There are regional and geographical variations, with the highest prevalence reported in Eastern, Western, Greater Accra¹¹ and Volta

region,¹⁵ and the lowest in the three northern regions.¹¹ Nevertheless, there is limited literature data on intra-regional variations in HIV testing rate in Ghana. This knowledge is important in identifying low testing zones in high testing regions and high testing zones in low testing regions for targeted testing interventions. In Ghana, HIV testing is offered in hospitals and clinics with testing compulsory for women attending antenatal clinics. It is necessary for citizens to know their HIV status in order to receive treatment and help curb the incidence of new infections. Therefore, the current study aimed to examine factors associated with HIV testing and spatial interpolation of the prevalence of HIV testing in Ghana using the nationally representative Demographic and Health Survey data. Understanding the geographic distribution of HIV testing will help public health officials and policy makers equitably distribute resources to areas that are less likely to be tested and to help reduce the spread of the virus.

Methods

Patient and Public Involvement

Our study analysed publicly available secondary data (GDHS 2014) from the demographic and health surveys database. Thus, patients and the public were not involved.

Study Design

This paper employed an analysis of secondary data using the 2014 Ghana Demographic and Health Survey (GDHS).¹⁶ As a cross-country survey, the GDHS is conducted to assess the general health of the population with a special focus on maternal and child health indicators as well as other themes of global health importance such as the prevalence of HIV prevalence, testing and treatment. The 2014 Ghana DHS data collection was operationalized by the Ghana Statistical Service (GSS) and the Ghana Health Service (GHS) with funding from the U.S. Agency for International Development and other international donors. Technical support was also

provided by the ICF international. The census frame used for the 2014 GDHS consisted of all enumeration areas demarcated during the 2010 Ghana’s Population and Housing Census. The 2014 GDHS was undertaken from early September to mid-December 2014. The 2014 GDHS adopted a multistage sampling in enrolling households and individuals. The first stage involved the random selection of clusters (enumeration areas). The second stage involved using systematic sampling to select households to be interviewed from clusters that had already been selected during the first stage. Sampling was also stratified to account for rural and urban variations. In all, 216 and 211 clusters were selected from urban and rural areas, respectively, making a total of 427 clusters. On average, about 30 households were chosen from each selected cluster constituting a total of 12,831 selected households in the 2014 GDHS. The probability of cluster selection was proportional to the cluster size and independent at each sampling stratum. The probability of cluster selection was proportional to the size of the cluster size and independent at each sampling stratum.

Study setting

The study setting is the republic of Ghana. Ghana is a lower-middle-income country in West Africa with a population of about 25 million people at the time of the 2014 GDHS. It shares boundaries Togo on the east, Burkina Faso on the north and northwest, and Côte d’Ivoire on the west.¹⁶

Measurements

The outcome variable under investigation was HIV testing in the past 12 months. This was assessed for each adult respondent in the survey by asking how long ago they had tested for HIV. For our study, we recoded the variable and grouped the cases who tested for HIV in the past 12

months as “1” and all others as “0”. The following sociodemographic and behavioural factors were included are sex, age, education level, marital status, religion, the total number of sexual partners in the past 12 months, history of sexually transmitted infections (STIs), household wealth index, place and region of residence. The household wealth index was already calculated and reported in the DHS data. It was estimated using household socioeconomic indicators such as the main roof and floor material of households, type of toilet facilities, source of drinking water, source of domestic cooking fuel, possession of television, radio, vehicle, motorcycles, agricultural land, farm animals amongst other movable and immovable assets. The GDHS employed factor analysis to allot weights to every household asset and a cumulative score was calculated from the allotted weights. Households were graded according to the aggregate scores. Aggregate wealth scores were classified using a percentage distribution and categorised into quintiles using discrete cut points. Poorest households were defined as wealth scores less than or equal to the 20th percentile; poorer households were those with scores greater than 20th percentile but less than or equal to 40th percentile; middle households were those with aggregate scores greater than the 40th percentile and less than or equal to the 60th percentile score; households with aggregate scores greater than the 60th percentile but less than or equal to the 80th percentile while households with aggregate scores greater than the 80th percentile were assigned as richest households.

Data collection, access, preparation, and analysis

Data collection was done by trained enumeration officials from GSS. As part of the data collection, respondents were asked if they had ever undergone testing for HIV. Data on other sociodemographic variables were collected as described above. The 2014 GDHS data used for analysis in this study is easily accessible at www.dhsprogram.com and can be freely downloaded

after an online request by individuals. Data was downloaded from the DHS program website after permission was obtained by the primary author, initially prepared in SPSS and analysed using STATA 16. The women and men data were separately downloaded comprising 9396 and 4388 cases, respectively. For the women dataset, sixteen cases with incomplete data on HIV testing and the covariates were dropped. Five hundred and thirty-three (533) men of 50 years and above were excluded from the analyses for men using ‘subpop’ function associated with the ‘svy’ command to allow a balanced comparison with the women. One case (1) with missing information on the outcome variable in the men datasets was excluded. The final sample sizes used for the analyses were 9380 women and 3854 men of 15 through 49 years. The key variables were selected and included in the final analysis using univariate, bivariate and multivariable approaches. We stratified bivariate analysis by gender and assessed for the presence of interaction effect of gender on the association between each study covariate and HIV testing among Ghanaians. The presence of significant interaction was assessed with the adjusted Wald Test. Multivariate estimates of the factors associated with HIV testing was performed separately for men and women samples.

The “gvselect”—Best subsets variable selection—in STATA was used to identify the best features to build models that explain the variability in HIV testing among Ghanaian men and women samples. As the name suggests, the “gvselect” performs best subsets variable selection.¹⁷ The variable selection is based on “the Furnival-Wilson leaps-and-bounds algorithm” published in 1974,¹⁸ which is “applied using the log-likelihoods of candidate models, allowing variable selection to be performed on a wide family of normal and nonnormal regression models”¹⁷ This method is described in the works of Lawless and Singhal published in 1978.¹⁹ The log-likelihood, Akaike's information criterion (AIC), and the Bayesian information criterion (BIC) are reported

for the best regressions at each predictor quantity.¹⁷ Thus, the model with the lowest AIC value is preferred. These variables (with their labels) were included in the “gvselect” equation: aaaV013 (age), aaaV106 (Education), aaaV502 (marital status), Religyn (religion), SexPart (sex partners including partner in last 12 months), aaaV763A (history of STI), aaaV190 (household wealth index), aaaV025 (urban-rural residence), aaaV024 (region of residence) (Additional file 1, Additional file 2). Coefficient plots for both the women and men models were generated using the “coefplot”, which is used for plotting regression coefficients.

We accounted for sample weight in the univariate and bivariate analysis. In the multivariate analysis, we used a complex survey design in STATA to account for sampling design. This was achieved using the “svyset” command to account for clusters or primary sampling units (n=427), sample strata (n=20) and sample weights. We used a generalized linear model (glm) with family set to “Poisson” to report prevalence ratio (PR) estimates instead of using a standard logistic regression used to report the odds ratio. We reported both crude and adjusted prevalence ratios (APR).

Spatial Analysis

We also performed spatial analysis to visualize HIV testing at the sub-regional level using clusters as the focus of the analysis. This was done using the prevR package in the R freeware for statistical analysis.²⁰ This package was specifically developed to perform spatial estimation of regional trends of a prevalence using data from complex surveys involving two-staged sampling.²⁰ With the aid of the functions available in the prevR package, we used the kernel estimator approach with adaptive bandwidths of an equal number of persons surveyed to produce a surface of HIV testing prevalence.²⁰ The main surface is an estimated HIV testing surface with parameter (N=233 for women sample and N=201 for men sample), a value that is chosen using

the Noptim() function in the prevR package.²⁰ The maps with the smoothing circle radius contours (in kilometres) have been added as supplementary figures (Women: S1 Figure, Men: S2 Figure). We used the “foreign” package in R to read the data in R whiles using “ggplot2” and “maptools” packages to demonstrate the HIV testing prevalence map. Spatial analysis was done using R version 3.5.3.²¹

Ethical considerations

Ethical approval for the 2014 Ghana DHS data collection was obtained from the Ethical Review Committee of the Ghana Health Service and the Institutional Review Board of ICF International. Enumerators obtained consent for enrolment from all respondents on behalf of GSS and the DHS program. We did not obtain any further consents. The application of spatial maps raises concerns for potential identification of respondents in their households on maps, especially for a sensitive topic such as HIV testing in West Africa. However, this was addressed as the spatial data included only the Global Positioning System (GPS) coordinates of the centre points of the clusters instead of the actual location of individual households. Moreover, GPS coordinates of the centre points of the clusters were displaced at a random angle by up to 2 km and 5 km for urban and rural clusters, respectively. Additionally, GPS locations for about 1% of the rural clusters were displaced by 10 km. This helps to ensure that the actual households will not be identifiable on maps, but the trade-off is that it makes the spatial analysis less accurate.

Results

Sample description

Table 1 describes the women and men samples, highlighting the association between HIV testing in the past 12 months and sociodemographic factors. In all, 15-49 years old women (9380 cases)

and men (3854 cases) were included in the analysis. In terms of quinary age distribution, the women showed equal proportion for the first three quinary age groups (17% each), with a gradual decline in the proportions with increasing age in the subsequent quinary age groups. Conversely, 22% of the men were aged 15-19years, 15% each for the 20-25years and 26-30years groups, and gradual decline in proportion with increasing age in the subsequent quinary age groups just like the pattern observed among the women. About 57% and 65% of women and men had attained secondary education, respectively. Approximately 33% and 48% of the women and men had never been in a union at the time of the survey, respectively. Religious affiliation was mainly Pentecostal/Charismatic among the women (41%) and men (31%). Only one percent of the women had had more than one sexual partner within the last 12 months preceding the survey compared to 14% among their men counterparts. More women (54%) than men (53%) resided in urban areas. About 13% of the women had screened and received results for HIV testing in the last 12 months preceding the survey compared to 6% in the men sample. For women, the following subgroups had a higher HIV screening rate compared to the national women average of 13%: Those aged 25-29 years (19%) and 30-34years (19%), women currently married (16%), those with previous STI (16%), women with only one sexual partner (16%), from richest households (18%) and those with higher than secondary education (26%). The following men subgroups had HIV screening rate higher than the national average of 6%: those aged 35-39years 11%, higher than secondary education (18%) and richest household (10%). Chi-square test of association showed that the following variables were significantly associated with HIV testing in both the women and men samples: age, education, marital status, religious affiliation, number of sexual partners within the last 12 months preceding the survey (wife/husband inclusive), wealth index, and the place and region of residence ($p < 0.05$). History of sexually transmitted infection (STI) in the last 12 months

was significantly associated with HIV testing in only the women sample in bivariate analysis.
(Table 1).

Table 1: summary statistics of study variables using survey-weighted data

	Women				Men			
Study variables	Number of observations	weighted percent age of the total population	HIV test in the past 12 months (weighted %)	p-value	Number of observations	weighted percent age of the total population	HIV test in the past 12 months (weighted %)	p-value
	9380	100	13		3854	100	6	
Age				p<0.0001				p<0.0001
15-19	1622	17	4		852	22	1	
20-24	1609	17	15		586	15	4	
25-29	1603	17	19		586	15	8	
30-34	1368	15	19		550	14	8	
35-39	1295	14	15		472	12	11	
40-44	1028	11	8		455	12	7	
45-49	855	9	5		353	9	7	
Education				p<0.0001				p<0.0001
None	1790	19	9		361	9	3	
Primary	1668	18	9		541	14	3	
Secondary	5326	57	14		2505	65	5	
Higher	596	6	26		446	12	18	
Marital Status				p<0.0001				p=0.001
Never in union	3089	33	8		1844	48	4	
Currently married	5311	57	16		1839	48	8	
Previously Married	980	10	8		171	4	8	

Religion				p<0.0001				p<0.0001
Catholic	940	10	12		414	11	8	
Protestants	1311	14	15		502	13	9	
Pentecostal/Charismatic	3851	41	13		1213	31	5	
Other Christians	1415	15	14		692	18	6	
Islam	1420	15	12		677	18	5	
Traditionalist	188	2	7		128	3	4	
No religion	253	3	8		228	6	7	
Sexual Partners				p<0.0001				p<0.0001
None	2695	29	6		1154	30	3	
One Partner	6566	70	16		2155	56	7	
Two or more	119	1	11		546	14	8	
Had STI				p=0.001				p=0.577
No	8958	95	13		3671	95	6	
Yes	422	5	16		183	5	5	
Household wealth Index				p<0.0001				p<0.0001
Poorest	1509	16	7		636	17	2	
Poorer	1634	17	10		646	17	4	
Middle	1933	21	12		768	20	4	
Richer	2113	23	14		845	22	7	
Richest	2191	23	18		959	25	10	
Urban-Rural residence				p<0.0001				p<0.0001
Urban	5043	54	15		2042	53	8	
Rural	4337	46	10		1812	47	4	
Region of residence				p<0.0001				p<0.0001
Western	1038	11	12		446	12	5	
Central	935	10	14		379	10	4	
Greater Accra	1897	20	15		828	21	9	
Volta	720	8	13		293	8	6	
Eastern	875	9	16		361	9	8	
Ashanti	1793	19	12		678	18	6	
Brong Ahafo	765	8	12		319	8	4	

Northern	785	8	8		315	8	4	
Upper East	358	4	11		145	4	9	
Upper West	214	2	12		90	2	4	
p-value: Statistical significance result of chi-square test of independence between the outcome and the study explanatory variables.								

Effect modification of gender on the relationship between each sociodemographic variable and HIV testing in Ghana

Gender was found to be a significant effect modifier on the relationship between HIV testing and all the sociodemographic variables under investigation : age ($p < 0.001$), marital status ($p < 0.001$), household wealth index ($p < 0.001$), educational level ($p < 0.001$), type of religion ($p < 0.001$), total number of sexual partners in the past 12 months ($p < 0.001$), STI status in the past 12 months ($p < 0.001$), place of residence ($p < 0.001$), and region of residence ($p < 0.001$) S1 Table.

Gender variations in the strength of association between HIV testing and sociodemographic factors

Regressors that were important to building a statistical model to explain the variability in HIV testing were somewhat different for women and men. For the women model, seven variables were identified as the appropriate correlate of HIV testing: age, education, marital status, sexual partners in the past 12 months, diagnosed with an STI in the past 12 months, household wealth, and region of residence (S1 Table, Figure 1). For the men model, six regressors were identified: age, education, religion, sexual partners in the past 12 months, urban-rural residence, and region of residence (S1 Table, Figure 2).

These four factors are consistent correlates of HIV testing for both women and men: age, education, sexual partners in the past 12 months, and region of residence (S1 Table, Figure 1 & 2). These consistent factors were first interpreted before the interpretation of the men or women model-

specific correlates. Although the direction of the association was generally the same for most variables in both women and men, the strength of the association varied by gender in some instances.

Relative to women aged 15-19years, the likelihood of HIV testing was about 2.1 times greater among their counterparts aged 20-24years [APR:2.107, 95% CI: 1.513, 2.935]. A similar pattern was observed for other older age groups 25-29yrs, 30-34yrs, 35-39yrs but not for women aged 40-44yrs, and 45-49years (S1 Table, Figure 1). Unlike the women counterparts, men in the older quinary age groups had a higher likelihood of HIV testing relative to their counterparts aged 15-19years. The magnitude of the effect was also greater in men compared to women (S1 Table, Figure 2).

Compared to women with no formal education, those with higher than secondary education had a 2.0 times greater likelihood of undergoing HIV screening [APR:2.026, 95% CI:1.510, 2.719] (S1 Table, Figure 1). A similar observation was made in the men sample but with a higher magnitude [APR:5.735, 95% CI:2.464, 13.35] (S1 Table, Figure 2). Women who had attained secondary education were 1.3 times likely to have undergone HIV screening compared to their counterparts with no formal education [APR:1.370, 95% CI:1.083, 1.731] (S1 Table, Figure 1). However, attainment of secondary school education was not a significant protective factor of HIV testing among men (S1 Table, Figure 2).

Women with only one sexual partner within the last 12 months were 1.5 times likely to have undergone HIV screening compared to their counterparts who had no sexual partners [APR:1.565, 95% CI:1.193,2.052] (S1 Table, Figure 1). However, this segment of the men population was not significantly associated with HIV testing among men (S1 Table, Figure 2).

Significant regional variations were observed in HIV testing among women and men. Residing in three regions was significantly associated with HIV testing compared to the greater Accra region among women, but only one region was significantly associated with the outcome among men in the same circumstances (S1 Table, Figure 1 & 2). For instance, compared to women living in the Greater Accra Region, those living in the Volta (APR: 1.282, 95% CI: 1.015, 1.619], Eastern [APR:1.338, 95% CI: 1.048,1.710], Upper East [APR:1.571, 95% CI: 1.096,2.253] and Upper West [APR:1.478, 95% CI:1.059, 2.062] regions had a higher likelihood of testing and receiving their HIV results (S1 Table, Figure 1). In the men sample, men living in the Upper East region had a 2.1 times higher likelihood of undergoing HIV screening [APR:2.188, 95%CI: 1.187, 4.032] compared to their counterparts in the Greater Accra Region (S1 Table, Figure 2).

Women who were currently married were 1.8 times likely to have undergone HIV screening compared to their counterparts who have never been in union [APR:1.855, 95%CI:1.487, 2.313] (S1 Table, Figure 1). The history of STI was not found to be an independent predictor of HIV screening in the women sample. Relative to the women in the poorest wealth quintiles, their counterparts who were in the poorer [APR:1.548, 95% CI:1.126, 2.128], middle [APR:1.724, 95% CI:1.259, 2.360], richer [APR:1.930, 95% CI:1.406, 2.648] and richest [2.190, 95%CI: 1.570, 3.056] wealth quintiles were more likely to have undergone HIV screening in the last 12years (S1 Table, Figure 1). Religion and urban-rural residence, although were identified as important features of HIV testing among men, were not significantly associated with HIV testing in the men model (S1 Table, Figure 2).

HIV testing prevalence in Ghana estimated by kernel estimator approach

Figure 3 shows the Ghana map (generated by the authors in QGIS version 3.10) with the ten regional demarcations and labels to facilitate the interpretation of the surface maps (Figure 3).

Overall, the HIV testing surface maps for both women and men samples revealed that the national and regional level estimates mask sub-regional level variations in HIV testing (Figure 4 & 5). The general observation for the surface maps of the women sample is that the areas with the highest HIV testing prevalence are in the southern regions while the lowest prevalence is found in the northern part of the country (Figure 4). These regions in southern Ghana include the Eastern, Greater Accra, Western, Eastern, and Volta. There are, however, areas in Upper East and West regions with relatively high HIV prevalence although the adjoining areas had low screening rate [the Northern region]. For the men surface map, there were areas of high testing prevalence in southern Ghana including the adjoining areas of Eastern, Greater Accra and Volta region in the surface maps of the men sample. It also showed a high screening rate among men in some clusters in the Ashanti and Upper East Regions (Figure 5). In summary, the surface maps showed inter-regional and intra-regional disparities in HIV screening rate in both the men and women sample. For instance, there are areas within each region with higher testing prevalence than others.

Discussion

This study conducted a multivariate analysis and spatial interpolation of the predictors of HIV testing in Ghana using nationally representative data, GDHS. To the authors' knowledge, this is the first study to analyse factors that influence recent HIV test prevalence in Ghana together with spatial interpolation using the GDHS, stratified by gender. We found that the prevalence of HIV testing was higher among women (13%) than men (6%). Our results have shown that sex, age, education level, marital status, total sexual partners in the past 12 months, household wealth

index and region of residence were significantly associated with HIV testing among women and/or men. For women, being within the age groups of 15-39 years, being currently married, attainment of post-secondary education, having only one sexual partner, and dwelling in certain regions with reference to greater Accra (Volta, Eastern, Upper West, and Upper East) were associated with a higher likelihood of HIV testing. For men, being older than 19 years, attainment of post-secondary education and dwelling in the Upper East region with reference to the greater Accra region were significantly associated with a higher likelihood of HIV testing.

The recent HIV testing prevalence found in our study was generally lower compared to estimates reported in Sierra Leone, Zambia, Lesotho, and Zimbabwe.²² All the countries with high rates of HIV testing are located in southern Africa and the high rates of testing in these countries were attributed to high rates of HIV prevalence, mandatory HIV testing at prenatal clinics and mobile clinics for HIV testing to mitigate the high prevalence of the virus.²²

There are some suggestive reasons for the relatively high HIV testing in Eastern, Greater Accra, and Central among both women and men in Ghana. The district—Lower Manya Krobo—that continually records the highest HIV prevalence in Ghana is in the Eastern region with a current estimate of 5.56% HIV prevalence.²³ Therefore, HIV reduction programs by government and non-governmental organizations (NGOs) are concentrated in the Eastern region.²⁴ HIV testing could be a proxy for access to healthcare facilities. Since the Greater Accra is the region with the highest number of healthcare facilities in Ghana, more people in the region may find it easy to screen for HIV.^{24 25} Our spatial interpolation revealed that there are areas in Ghana with higher HIV testing prevalence compared to the national and regional estimates. For example, in the Western Region, regional HIV testing prevalence was 12%, however, the spatial interpolation identified some clusters to be as low as 5% and some as high as 30%. These within region

variations underscore the importance of applying spatial interpolation in population-based studies to unmask the hidden details which can help design targeted interventions.

Women, in general, had a greater likelihood of HIV testing compared to their men counterparts, although below the national and global 90-90-90 targets, this is in agreement with previous studies.^{11 26} This can partly be explained by the fact that HIV testing for women during prenatal care which aims at reducing mother-to-child transmission of HIV.^{27 28} We found that compared to all age groups, adolescents between ages 15 and 19 years tend to have the lowest likelihood of getting tested for HIV. This finding is critical to public health because earlier studies have reported that higher rates of HIV infection among adolescents are more likely due to being engaged in risky behaviour and unsafe sex practices which put them at risk of contracting HIV.^{29 30} Therefore, health policymakers should target adolescents with health education and mass HIV testing programs and interventions. In Ghana, health testing such as breast cancer testing among older adult women has been reported to be associated with participation in club meetings.³¹ Given that many youth clubs exist in Ghana, they could be encouraged and incentivised to add HIV testing to their club activities.

Our results showed that educational status was a significant predictor of HIV testing among both women and men. People with higher education may have adequate knowledge and understanding of the implications of testing for HIV, thereby resulting in their likelihood to patronize testing services. Our finding concurs with previous studies,^{32 33} that reported a positive relationship between education and HIV testing.

We found that women who were currently married were more likely to be tested than those who have never married. For men, marital status was not significantly associated with HIV testing. Generally, in most African countries including Ghana, religious institutions and local

governments require mandatory pre-marital HIV testing as a means to combat the spread of HIV among newly married couples.^{34 35} Therefore, married people have the possibility of being tested for HIV compared to their unmarried counterparts. Although contentious and said to be a source of stigmatization and human right violation to those who test HIV positive,^{34 36 37} mandatory pre-marital HIV testing is said to be an effective way of people knowing their status. Therefore, there is a need for collaboration between public health officials and other leaders such as religious and community leaders to partner to help improve HIV testing in the communities.

Unlike men, current marriage among women was significantly associated with an increased likelihood of HIV testing. This observation can be explained by the fact that sexual activities and childbirth are socially acceptable among married couples in Ghana.³⁸ For most women, marriage sometimes results in childbirth and HIV testing is done for all women who visit antenatal as part of the prevention of mother to child transmission policy in Ghana.³⁹ This service is generally exclusive for pregnant women and does not apply to men. For currently married men, an HIV test is not required even if their wives attend antenatal care services. To encourage men to test for HIV, it is important that HIV testing is made compulsory for husbands or partners of women attending antenatal care.

Our findings also highlighted some noteworthy variations in the factors associated with HIV testing between men and women. Primary education was significantly and independently associated with an increased likelihood of HIV testing in women and men, but the effect was greater for men than women. This finding is important because it reinforces the health value of universal basic education in Ghana and the need to encourage women to attain universal basic education for improved health outcomes. Also, the magnitude of the effect of increasing age on HIV testing was generally larger for men than women. Moreover, men in age groups 40-49yrs

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2
3 had a significantly higher likelihood of having undergone HIV testing compared to men aged 15-
4
5 19 years but women in these age brackets were not significantly associated with HIV testing.
6
7 This can be partly explained by the fact that most women aged 45-49 might have reached
8
9 menopause and their engagement in active sexual activities might have reduced⁴⁰ and hence were
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11 probably not targeted for HIV testing by a public health professional. On the contrary, their men
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13 counterparts are generally sexually active and were more likely to have been targeted for HIV
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15 testing by public health professionals.⁴¹ We also found that women who had one sexual partner in
16
17 the past 12 months were significantly more likely to undergo HIV testing, but this association
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19 was absent among men.
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24 Another noteworthy gender variation was observed for the effect of household wealth on
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26 HIV testing. We found that wealth status predicts the likelihood of HIV testing among Ghanaian
27
28 women only. Compared to the women from the poorest household, we found a higher likelihood
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30 for HIV testing among women in the poorer, middle, richer, and richest households. This finding
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32 is consistent with previous studies.^{32 37 42} The cost associated with the testing could be a barrier
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34 for people with low socioeconomic status to get tested. These findings suggest the need for
35
36 sensitization campaigns targeting communities and people with a low level of education and
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38 socioeconomic status to increase their awareness of the importance of HIV testing. This could be
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40 done through targeted outreach such as mobile clinics and integrating HIV testing into routine
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42 healthcare services, improving home-based and self-testing, and subsidising the cost of the
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44 testing. Community leaders such as chiefs and religious leaders should also be involved in
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46 promoting HIV testing. This finding implies that any policy which can increase the economic
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48 standings of households, no matter how small the change may be, has a benefit on health care
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utilization as far as HIV testing, especially for women. This finding is similar to a study conducted among the same population in Mozambique using the DHS dataset.³⁷

Strength and Limitation

The current study used a large, nationally representative survey data set and employed a robust methodology for analyses. We stratified our analysis by gender which revealed interesting findings which can guide policy to target each gender to ensure efficiency and effectiveness of policy interventions. We employed spatial interpolation techniques that have advantages over standard statistical techniques to identify geographical variations of HIV testing prevalence in Ghana. This may be of population health significance in the effort to meet the UNAIDS 90-90-90 target not only in Ghana but in other sub-Saharan African countries. Cluster analysis with the Scan Statistics method adjusts for population density and decreases selection bias as the clusters are explored without previous knowledge of their size, location or period.⁴³ Furthermore, our study uncovered the population that is most at risk of not being tested for HIV and geographical locations with low HIV testing in Ghana. These findings could serve as a framework for public health officials to design targeted intervention to increase HIV testing.

Our findings, however, are subject to limitations that must be taken into consideration. As characteristics of all cross-sectional studies, our study could neither establish temporality nor causality of the observed association. It is important to note that all the variables in this study were self-reported and this could have introduced recall or social desirability bias. Also, we were not able to ascertain the actual reasons for participant’s prior HIV testing and therefore this was not accounted for in our analysis. Moreover, a limitation with the visualization of HIV testing using spatial maps is that the testing rate is dispersed across all pixels regardless of the presence or absence of population settlements. Despite these limitations, this study has provided profound

insights from a population-level survey analysis as well as a spatial analysis of HIV testing prevalence in Ghana for informed public health action.

Conclusion

In conclusion, the study findings could help public health officials to better understand factors associated with HIV testing among the Ghanaian general population by showing the areas and at risk-population for targeted HIV intervention programs. We found that 13% of women and 6% men of in the population in Ghana have ever been screened for HIV. The highest regional HIV testing prevalence was recorded in the Eastern region (16%) and that of men was recorded in the Greater Accra region (9%). The spatial interpolated prevalence map further revealed intraregional level differences in HIV testing estimates. We also found gender variations in the factors associated with HIV testing which could guide policy interventions. Expansion of HIV testing, outreach through mobile clinics, home-based and self-testing, wide-ranging coverage through outreach programs, community-based approaches, and integration of opportunities or HIV testing during regular medical care is critical. These myriad approaches will be integral in reaching all persons with sub-clinical HIV infections in sub-Saharan Africa for life-saving treatment.

Figure Legends:

Figure 1: Coefficient plot showing the correlates of HIV testing among Ghanaian women

Figure 2: Coefficient plot showing the correlates of HIV testing among Ghanaian men

Figure 3: Ghana map showing the regional demarcation and label

Figure 4: HIV testing prevalence among women in Ghana estimated by kernel estimator approach

Figure 5: HIV testing prevalence among men in Ghana estimated by kernel estimator approach

Conflict of Interest

The authors declare that they have no competing interests.

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Data availability statement

The 2014 GDHS data are publicly available upon a simple registration-access request so data used for this study can be obtained from the DHS website at https://dhsprogram.com/data/dataset_admin/index.cfm.

Authors' contributions

All authors contributed to the design of the study. JJN obtained permission and downloaded datasets from the DHS program website, and contributed to the drafting and review of the manuscript. HOD and PA contributed to the analysis of data and drafting of the manuscript. PAD, RKA and ED participated in the drafting of the manuscript. All authors critically reviewed the manuscript and approved the final version.

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References

1. World Health Organization. HIV/AIDS: Data and Statistics 2018 [cited 2019. Available from: <https://www.who.int/hiv/data/en/> accessed August 10, 2019.

2. UNAIDS. Global HIV & AIDS statistics — 2019 fact sheet 2019 [cited 2020 June 20]. Available from: <https://www.unaids.org/en/resources/fact-sheet> accessed June 16 2020.

3. World Health Organization. HIV/AIDS Fact Sheet Geneva: World Health Organization 2019 [updated November 15, 2019;2019]. Available from: <https://www.who.int/en/news-room/fact-sheets/detail/hiv-aids> accessed November 25 2019.
4. Kharsany AB, Karim QA. HIV infection and AIDS in sub-Saharan Africa: current status, challenges and opportunities. *The open AIDS journal* 2016;10:34.
5. Narin P, Yamamoto E, Saw YM, et al. Factors associated with HIV testing among the general male population in Cambodia: A secondary data analysis of the Demographic Health Survey in 2005, 2010, and 2014. *PloS one* 2019;14(7):e0219820.
6. UNAIDS. AIDS JUNPo: 90–90–90: an ambitious treatment target to help end the AIDS epidemic. Geneva: UNAIDS 2014
7. Asamoah CK, Asamoah BO, Agardh A. A generation at risk: A cross-sectional study on HIV/AIDS knowledge, exposure to mass media, and stigmatizing behaviors among young women aged 15–24 years in Ghana. *Global health action* 2017;10(1):1331538.
8. Gómez-Ayerbe C, Martínez-Sanz J, Muriel A, et al. Impact of a structured HIV testing program in a hospital emergency department and a primary care center. *PloS one* 2019;14(8):e0220375.
9. Koku EF. Stigma, sexual risk and desire for HIV tests in Ghana. *Sexual health* 2011;8(1):110-19.
10. Laar A, DeBruin D. Key populations and human rights in the context of HIV services rendition in Ghana. *BMC International Health and Human Rights* 2017;17(1):1-10.
11. Ali H, Amoyaw F, Baden D, et al. Ghana's HIV epidemic and PEPFAR's contribution towards epidemic control. *Ghana medical journal* 2019;53(1):59-62.
12. Addo SA, Abdulai M, Yawson A, et al. Availability of HIV services along the continuum of HIV testing, care and treatment in Ghana. *BMC Health Services Research* 2018;18(1):739.
13. Van Hulst M, Sagoe KW, Vermande JE, et al. Cost-effectiveness of HIV screening of blood donations in Accra (Ghana). *Value in Health* 2008;11(5):809-19.
14. John Nutor J, Duodu PA, Agbadi P, et al. Predictors of high HIV+ prevalence in Mozambique: A complex samples logistic regression modeling and spatial mapping approaches. *Plos one* 2020;15(6):e0234034.
15. Osei-Yeboah J, Lokpo SY, Ussher FA, et al. The Epidemiology of Human Immunodeficiency Virus (HIV) and Syphilis in Ghana: A Five-Year Single Urban Site Parallel Population-Based Analysis vis-à-vis the Sentinel Survey. *Journal of tropical medicine* 2018;2018
16. GSS G. Ghana statistical service (GSS), Ghana health service (GHS), and ICF macro. Accra: Ghana Demogr Health Surv 2009;2008:79-96.
17. Lindsey C, Sheather S. Best subsets variable selection in nonnormal regression models. *The Stata Journal* 2015;15(4):1046-59.
18. Furnival GM, Wilson RW. Regressions by leaps and bounds. *Technometrics* 2000;42(1):69-79.
19. Lawless J, Singhal K. Efficient screening of nonnormal regression models. *Biometrics* 1978:318-27.
20. Larmarange J, Vallo R, Yaro S, et al. Methods for mapping regional trends of HIV prevalence from Demographic and Health Surveys (DHS). *Cybergeo: European Journal of Geography* 2011
21. Team RC. R: A language and environment for statistical computing. 2013
22. Staveteig S, Croft TN, Kampa KT, et al. Reaching the 'first 90': Gaps in coverage of HIV testing among people living with HIV in 16 African countries. *PLoS One* 2017;12(10):e0186316. doi: 10.1371/journal.pone.0186316 [published Online First: 2017/10/13]
23. Ghana AIDS Commission. National HIV and AIDS Policy: Universal Access to HIV Prevention, Treatment and Care Services towards Ending AIDS as a Public Health Threat. Accra, Ghana. 2019 [cited 2020 July 1]. Available from: [https://www.ghanais.gov.gh/mcadmin/Uploads/nationalHIVandAIDSPolicy\(2\).pdf](https://www.ghanais.gov.gh/mcadmin/Uploads/nationalHIVandAIDSPolicy(2).pdf) accessed July 1 2020.

24. Hushie M. Public-non-governmental organisation partnerships for health: an exploratory study with case studies from recent Ghanaian experience. *BMC Public Health* 2016;16(1):963.

25. Tun W, Okal J, Schenk K, et al. Limited accessibility to HIV services for persons with disabilities living with HIV in Ghana, Uganda and Zambia. *Journal of the International AIDS Society* 2016;19:20829.

26. Sanga Z, Kapanda G, Msuya S, et al. Factors influencing the uptake of Voluntary HIV Counseling and Testing among secondary school students in Arusha City, Tanzania: a cross sectional study. *BMC Public Health* 2015;15(1):452.

27. Nyuzaghl J, Ohene S, Odoi-Agyarko K. Acceptability of routine offer of HIV Testing (opt-out approach) among pregnant women in the Wa municipality. *Ghana medical journal* 2011;45(1)

28. Camlin CS, Ssemmondo E, Chamie G, et al. Men "missing" from population-based HIV testing: insights from qualitative research. *AIDS Care* 2016;28 Suppl 3(Suppl 3):67-73. doi: 10.1080/09540121.2016.1164806 [published Online First: 2016/07/16]

29. Dellar RC, Dlamini S, Karim QA. Adolescent girls and young women: key populations for HIV epidemic control. *Journal of the International AIDS Society* 2015;18:19408.

30. Kim YK, Small E, Okumu M. School-based HIV/AIDS education, risky sexual behaviors, and HIV testing among high school students in the United States. *Soc Work Health Care* 2019;58(3):258-73. doi: 10.1080/00981389.2018.1558163 [published Online First: 2018/12/18]

31. Agyemang AF, Tei-Muno AN, Dzomeku VM, et al. The prevalence and predictive factors of breast cancer screening among older Ghanaian women. *Heliyon* 2020;6(4):e03838.

32. Lépine A, Terris-Prestholt F, Vickerman P. Determinants of HIV testing among Nigerian couples: a multilevel modelling approach. *Health policy and planning* 2015;30(5):579-92.

33. Mirandola M, Gios L, Joanna Davis R, et al. Socio-demographic factors predicting HIV test seeking behaviour among MSM in 6 EU cities. *The European Journal of Public Health* 2017;27(2):313-18.

34. Akoku DA, Tihnje MA, Tarh EO, et al. Predictors of willingness to accept pre-marital HIV testing and intention to sero-sort marital partners; risks and consequences: Findings from a population-based study in Cameroon. *PloS one* 2018;13(12):e0208890.

35. Barmania S, Aljunid SM. Premarital HIV testing in Malaysia: a qualitative exploratory study on the views of major stakeholders involved in HIV prevention. *BMC international health and human rights* 2017;17(1):1-10.

36. Ifemeje S. Mandatory premarital HIV testing policy in Nigeria: a gross violation of the rights of people living with HIV/AIDS. *The International Journal of Human Rights* 2012;16(3):401-10.

37. Agbadi P, Nutor JJ, Darkwah E, et al. Covariates and Spatial Interpolation of HIV Screening in Mozambique: Insight from the 2015 AIDS Indicator Survey. *International Journal of Environmental Research and Public Health* 2020;17(16):5630.

38. Elleamoh GE, Dake FA. "Cementing" marriages through childbearing in subsequent unions: Insights into fertility differentials among first-time married and remarried women in Ghana. *PloS one* 2019;14(10):e0222994.

39. Ejigu Y, Tadesse B. HIV testing during pregnancy for prevention of mother-to-child transmission of HIV in Ethiopia. *PLoS One* 2018;13(8):e0201886. doi: 10.1371/journal.pone.0201886 [published Online First: 2018/08/10]

40. Krasnow SS, Maglio A-S. Female sexual desire: what helps, what hinders, and what women want. *Sexual and Relationship Therapy* 2019:1-29.

41. Gewirtz-Meydan A, Ayalon L. Why do older adults have sex? Approach and avoidance sexual motives among older women and men. *The Journal of Sex Research* 2019;56(7):870-81.

42. Agha S. Factors associated with HIV testing and condom use in Mozambique: implications for programs. *Reproductive Health* 2012;9(1):20.

43. Chimoyi LA, Musenge E. Spatial analysis of factors associated with HIV infection among young people in Uganda, 2011. *BMC public health* 2014;14(1):555.

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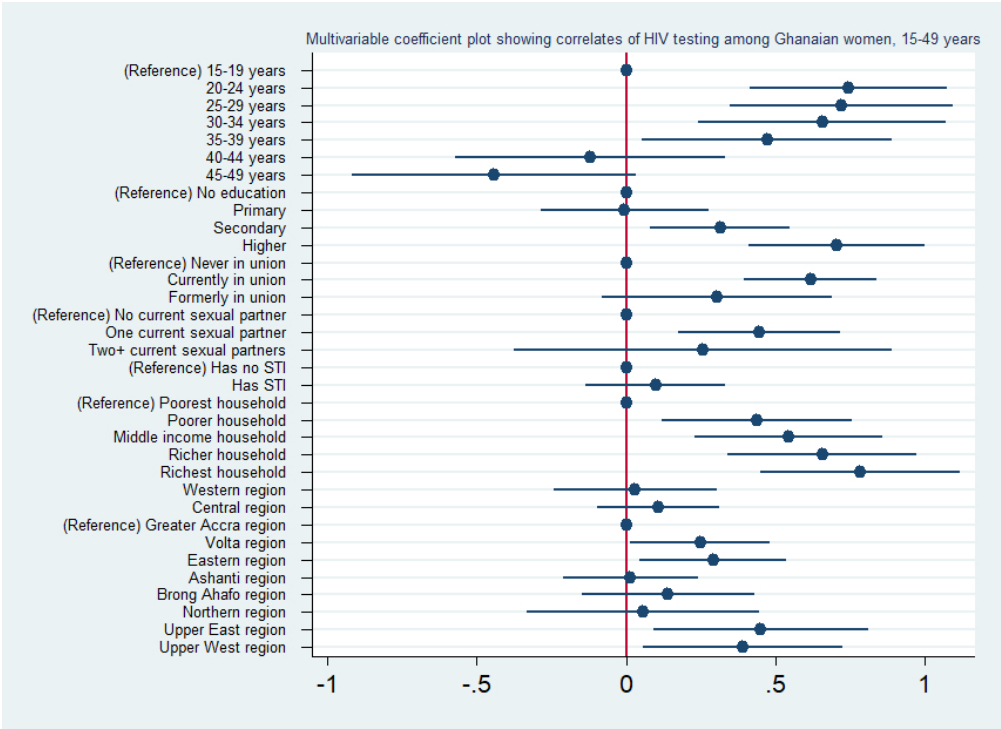


Figure 1: Coefficient plot showing the correlates of HIV testing among Ghanaian women

300x218mm (72 x 72 DPI)

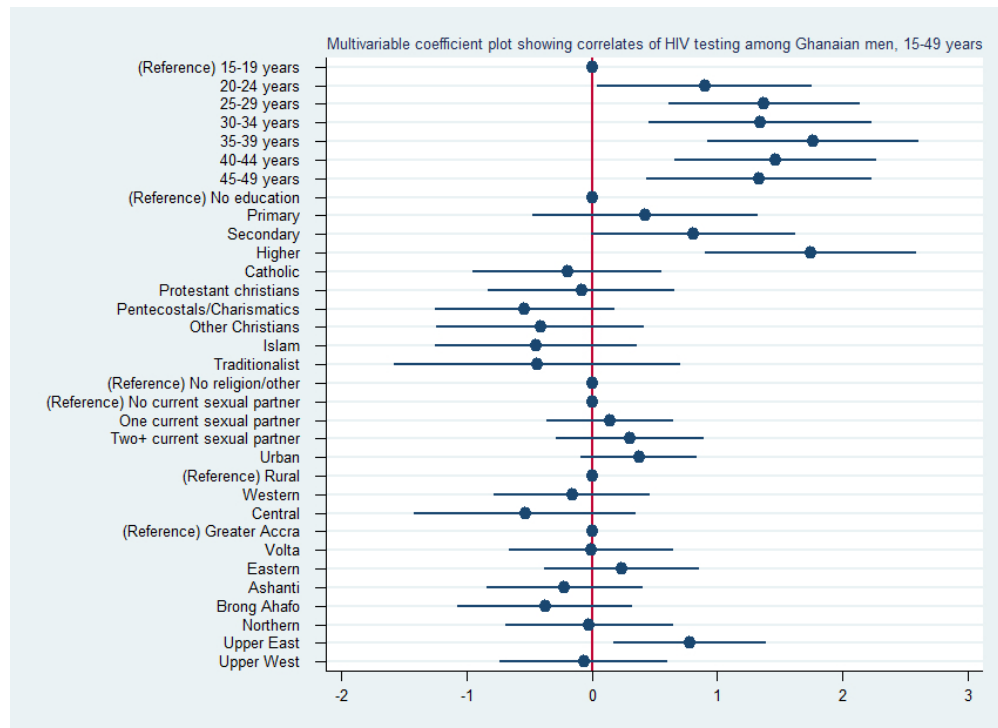


Figure 2: Coefficient plot showing the correlates of HIV testing among Ghanaian men

300x218mm (72 x 72 DPI)



Figure 3: Ghana map showing the regional demarcation and label

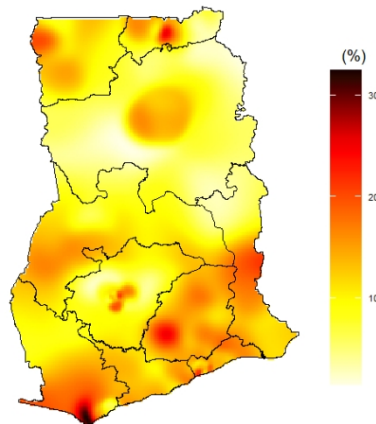


Figure 4: HIV testing prevalence among women in Ghana estimated by kernel estimator approach

317x151mm (96 x 96 DPI)

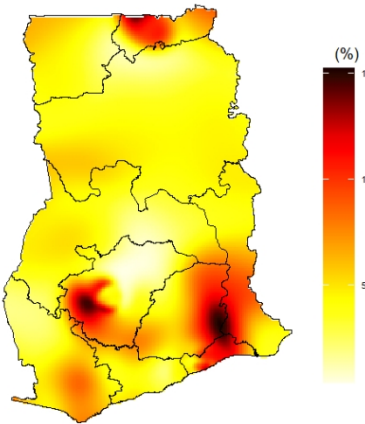


Figure 5: HIV testing prevalence among men in Ghana estimated by kernel estimator approach

317x151mm (96 x 96 DPI)

Supplementary table

S1 Table: The Correlates of HIV testing in the last 12 months, stratified by gender

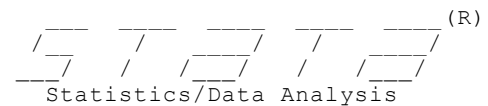
	Women		Men	
	Full model	Reduced model	Full model	Reduced model
	APR [95% CI]	APR [95% CI]	APR [95% CI]	APR [95% CI]
Age	p< 0.0001	p< 0.0001	P=0.0036	P=0.0005
15-19	Ref	Ref	Ref	Ref
20-24	2.112*** [1.517,2.941]	2.107*** [1.513,2.935]	2.428* [1.034,5.703]	2.459* [1.040,5.812]
25-29	2.059*** [1.418,2.991]	2.057*** [1.418,2.986]	3.915*** [1.830,8.373]	3.955*** [1.840,8.503]
30-34	1.930** [1.273,2.925]	1.929** [1.275,2.919]	3.846** [1.567,9.440]	3.841** [1.581,9.331]
35-39	1.599* [1.052,2.431]	1.604* [1.054,2.439]	5.750*** [2.340,14.13]	5.855*** [2.519,13.61]
40-44	0.886 [0.562,1.395]	0.887 [0.564,1.396]	4.233** [1.794,9.986]	4.335*** [1.938,9.696]
45-49	0.637 [0.395,1.029]	0.642 [0.399,1.033]	3.792** [1.498,9.600]	3.812** [1.549,9.385]
Education	p< 0.0001	p< 0.0001	P=0.0001	p< 0.0001
None	Ref	Ref	Ref	Ref
Primary	0.997 [0.759,1.310]	0.994 [0.751,1.317]	1.408 [0.561,3.529]	1.527 [0.622,3.749]
Secondary	1.378** [1.105,1.718]	1.370** [1.083,1.731]	1.783 [0.758,4.199]	2.246 [0.996,5.064]
Higher	2.064*** [1.560,2.731]	2.026*** [1.510,2.719]	3.978** [1.594,9.930]	5.735*** [2.464,13.35]
Marital Status	p< 0.0001	p< 0.0001	P=0.9405	
Never in union	Ref	Ref	Ref	Ref

Currently married	1.881*** [1.507,2.349]	1.855*** [1.487,2.313]	0.926 [0.603,1.423]	--
Previously Married	1.366 [0.932,2.001]	1.354 [0.921,1.991]	0.937 [0.447,1.967]	--
Religion	P=0.6894		P=0.3851	P=0.4188
Catholic	1.141 [0.708,1.841]		0.741 [0.350,1.570]	0.823 [0.387,1.750]
Protestants	1.349 [0.853,2.132]	--	0.839 [0.397,1.774]	0.921 [0.438,1.935]
Pentecostal/Charismatic	1.222 [0.780,1.914]	--	0.533 [0.259,1.096]	0.585 [0.286,1.196]
Other Christians	1.295 [0.801,2.094]	--	0.602 [0.263,1.378]	0.662 [0.289,1.513]
Islam	1.312 [0.812,2.121]	--	0.583 [0.256,1.327]	0.641 [0.287,1.434]
Traditionalist	1.101 [0.540,2.245]	--	0.718 [0.241,2.140]	0.647 [0.207,2.020]
Ref	Ref	Ref	Ref	Ref
Sexual Partners	P=0.0052	P=0.0052	P=0.5687	P=0.5808
None	Ref	Ref	Ref	Ref
One Partner	1.566** [1.194,2.055]	1.565** [1.193,2.052]	1.185 [0.688,2.043]	1.156 [0.694,1.925]
Two or more	1.299 [0.682,2.474]	1.292 [0.685,2.435]	1.394 [0.746,2.603]	1.359 [0.752,2.457]
Had STI	P=0.4229	P=0.4091	P=0.2970	
No	Ref	Ref	Ref	Ref
Yes	1.100 [0.871,1.388]	1.103 [0.873,1.393]	0.706 [0.366,1.360]	--
Household wealth Index	P=0.0306	P=0.0003	P=0.049	

Poorest	Ref	Ref	Ref	Ref
Poorer	1.479* [1.085,2.016]	1.548** [1.126,2.128]	2.309* [1.090,4.890]	--
Middle	1.577** [1.146,2.169]	1.724*** [1.259,2.360]	1.894 [0.848,4.233]	--
Richer	1.696** [1.188,2.422]	1.930*** [1.406,2.648]	3.283** [1.363,7.909]	--
Richest	1.860** [1.268,2.729]	2.190*** [1.570,3.056]	3.410** [1.366,8.515]	--
Urban-Rural residence	P=0.1997		P=0.8940	P=0.1147
Urban	1.137 [0.934,1.385]	--	1.039 [0.593,1.819]	1.455 [0.913,2.320]
Rural	Ref	Ref	Ref	Ref
Region of residence	P=0.0710	P=0.0759	P=0.0001	P=0.0123
Western	1.059 [0.809,1.387]	1.031 [0.784,1.356]	0.861 [0.470,1.578]	0.854 [0.458,1.592]
Central	1.137 [0.925,1.398]	1.114 [0.909,1.365]	0.581 [0.235,1.437]	0.586 [0.242,1.420]
Greater Accra	Ref	Ref	Ref	Ref
Volta	1.317* [1.049,1.652]	1.282* [1.015,1.619]	1.153 [0.594,2.238]	0.995 [0.518,1.910]
Eastern	1.339* [1.048,1.710]	1.338* [1.048,1.710]	1.393 [0.759,2.556]	1.270 [0.687,2.348]
Ashanti	1.023 [0.816,1.283]	1.015 [0.809,1.273]	0.810 [0.440,1.491]	0.803 [0.430,1.500]
Brong Ahafo	1.129 [0.848,1.501]	1.151 [0.863,1.536]	0.814 [0.409,1.619]	0.687 [0.342,1.383]
Northern	1.036 [0.699,1.537]	1.059 [0.718,1.563]	1.321 [0.707,2.469]	0.980 [0.504,1.908]

Upper East	1.542* [1.060,2.242]	1.571* [1.096,2.253]	3.522*** [1.868,6.641]	2.188* [1.187,4.032]
Upper West	1.480* [1.039,2.109]	1.478* [1.059,2.062]	1.166 [0.584,2.330]	0.937 [0.478,1.835]
model details				
Strata	20	20	20	20
PSUs	427	427	426	426
Observations	9380	9380	3854	3854
Population size	9381.3827	9381.3827	3868.3305	3868.3305
Design df	407	407	406	406
F	(34, 374) = 13.75	(27, 381) = 17.15	(34, 373) = 5.22	(27, 380) = 5.79
Prob > F	< 0.00001	< 0.00001	< 0.00001	< 0.00001
AIC	6991.539	6989.227	1698.33	1693.87
APR: Adjusted Prevalence Ratio				
Exponentiated coefficients; 95% confidence intervals in brackets * p<0.05, ** p<0.01, *** p<0.001				

Model Selection for Female HIV test Friday April 9 01:47:30 2021 Page 1



User: Pascal Agbadi

Project: HIV TEST IN LAST 12 MONTHS{space -4}

1 . ***model selection

2 . gvselect <term> aaaV013 aaaV106 aaaV502 Religyn SexPart aaaV763A aaaV190 aaaV025 aaaV024: poisson

Optimal models:

#	Preds	LL	AIC	BIC
1		-3593.924	7191.847	7206.14
2		-3537.579	7081.158	7102.597
3		-3519.462	7046.923	7075.508
4		-3506.324	7022.649	7058.38
5		-3493.142	6998.284	7041.162
6		-3487.799	6989.598	7039.623
7		-3486.613	6989.227	7046.397
8		-3486.113	6990.226	7054.543
9		-3485.769	6991.539	7063.002

predictors for each model:

```

1 : aaaV106
2 : SexPart aaaV106
3 : SexPart aaaV502 aaaV106
4 : SexPart aaaV502 aaaV106 aaaV013
5 : SexPart aaaV502 aaaV106 aaaV013 aaaV190
6 : SexPart aaaV502 aaaV106 aaaV013 aaaV190 aaaV024
7 : SexPart aaaV502 aaaV106 aaaV013 aaaV190 aaaV024 aaaV763A
8 : SexPart aaaV502 aaaV106 aaaV013 aaaV190 aaaV024 aaaV763A Religyn
9 : SexPart aaaV502 aaaV106 aaaV013 aaaV190 aaaV024 aaaV763A Religyn aaaV025

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1      Model Selection for Male HIV test   Friday April 9 03:38:14 2021   Page 1
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Statistics/Data Analysis

(R)

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                                User: Pascal Agbadi
                                Project: HIV TEST IN LAST 12 MONTHS{space -4}

1 . ***model selection
2 . gvselect <term> aaaMV013 aaaMV106 aaaMV502 Religyn SexPart aaaMV763A aaaMV190 aaaMV025 aaaMV024:
  532 observations containing missing predictor values

Optimal models:

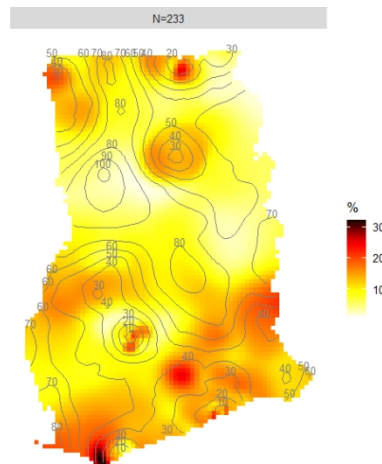
# Preds      LL      AIC      BIC
1 -873.6708  1751.342  1763.855
2 -856.861   1719.722  1738.493
3 -849.077   1706.154  1731.181
4 -845.0365  1700.073  1731.357
5 -841.0683  1694.137  1731.678
6 -839.9352  1693.87  1737.669
7 -839.2897  1694.579  1744.634
8 -839.2115  1696.423  1752.735
9 -839.1649  1698.33  1760.898

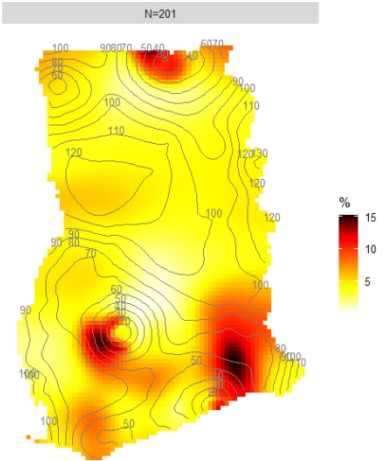
predictors for each model:

1 : aaaMV106
2 : aaaMV106 aaaMV013
3 : aaaMV106 aaaMV013 aaaMV025
4 : aaaMV106 aaaMV013 SexPart aaaMV025
5 : aaaMV106 aaaMV013 aaaMV024 SexPart aaaMV025
6 : aaaMV106 aaaMV013 aaaMV024 SexPart aaaMV025 Religyn
7 : aaaMV106 aaaMV013 aaaMV024 SexPart aaaMV025 Religyn aaaMV190
8 : aaaMV106 aaaMV013 aaaMV024 SexPart aaaMV025 Religyn aaaMV190 aaaMV763A
9 : aaaMV106 aaaMV013 aaaMV024 SexPart aaaMV025 Religyn aaaMV190 aaaMV763A aaaMV502

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317x151mm (96 x 96 DPI)